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LOCOMOTION AND TRANSPORT,

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CHAPTER I.

INFLUENCE OF IMPROVED TRANSPORT ON CIVILISATION.

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1. THE art by which the products of labour and thought, and the persons who labour and think, are transferred from place to place, is, more than any other, essential to social advancement. Without it no other art can progress. A people who do not possess it cannot be said to have emerged from barbarism. A people who have not made some advances in it, cannot yet have risen above a low state of civilisation. Nevertheless, this art has been, of all others, the latest in attaining a state of perfection, so late, indeed, that the future historian of social progress will record, without any real violation of truth, that its creation is one of the events which have most eminently signalised the present age and generation. For, although transport by land and water was practised by our forefathers, its condition was so immeasurably below that to which it has been carried in our times, that a more adequate idea of its actual state will be conveyed by calling it a new art, than by describing it as an improvement on the old one.

2. But if human invention has been late in directing its powers to this object, it must be admitted to have nobly compensated for the tardiness of its action by the incomparable rapidity of advancement it has produced, when once they have been brought into play. Within a hundred years, more has been accomplished in facilitating and expediting intercommunication, than was effected from the creation of the world to the middle of the last century. This statement may, perhaps, appear strained and exaggerated, but it will bear the test of examination.

3. The geographical conditions of the world, the distribution of the people who inhabit it, and the exclusive appropriation of its natural productions destined for their use to the various countries of which it consists, have imposed on mankind the necessity of intercommunication and commerce. Commerce is nothing more than the interchange of the productions of industry between people and people. Such interchange presupposes the existence of the art of transport by land and water. In proportion to the perfection of this art will be the extent of commerce.

A people incapable of communicating with others must subsist exclusively upon the productions of its own labour and its own soil. But nature has given us desires after the productions of other soils and other climates. Besides this, the productions of each particular soil or country are obtainable in superfluity. They are infinitely more in quantity than the people by whom and amidst whom they are produced have need of; while other and distant peoples are in a like situation, having a superfluity of some products and an insufficiency or a total absence of others. The people of South Carolina and Georgia have a superfluity of cotton, the people of the West India Islands have a superfluity of

coffee and tobacco, the people of Louisiana have a superfluity of sugar, the people who inhabit the vast valley of the Upper Mississippi and Missouri have a superfluity of corn and cattle, the people of civilised Europe have a superfluity of the products of mechanical labour, those of France have a superfluity of silk goods, those of England of manufactured cotton, pottery, and hardware. Each of these various peoples is able and willing to supply the others with those productions in which themselves abound, and to receive in exchange those of which they stand in need, and which abound elsewhere.

4. But, to accomplish such interchanges, means of transport must be provided, and this transport must be sufficiently cheap, speedy, safe, and regular, to enable these several productions to reach their consumers, and be delivered on such terms and conditions as will be compatible with the ability to purchase them.

5. Among the advantages which attend improved means of transport, one of the most prominent is that of lowering the price of all commodities whatever in the market of consumption, and thereby stimulating production. The price paid for an article by its consumer consists of two elements: 1st, the price paid for the article to its producer at the place of its production; and, 2ndly, the expense of conveying it from that place to the consumer. In this latter element is included the cost of its transport and the commercial expenses connected with such transport. These last include a variety of items which enter largely into the price of the commodity, such as the cost of transport, properly so called, the interest on the price paid to the producer proportionate to the time which elapses before it reaches the consumer, the insurance against damage or loss during the transport. This insurance must be paid directly or indirectly by the consumer. If it be not effected by those who convey the commodity to the consumer, the value of the goods which may be lost or damaged in the transport will necessarily be charged in the price of those which arrive safe. In either case the consumer pays the insurance. There are also the charges for storage, packing, transhipment, and a variety of other commercial details, the total of which forms a large proportion of the ultimate price.

In many cases, these expenses incidental to transport amount to considerably more than half the real price of the article; in some they amount to three-fourths or four-fifths, or even a larger proportion.

6. Let us take the example of raw cotton produced on the plains of South Carolina or Georgia. This article is packed in bales at the *place of production. These* are then transported to Charleston *or Savannah, whence they* are exported to Liverpool. Arriving

at Liverpool, they are transferred upon the railway, by which they are transported to Manchester, Stockport, Preston, or some other seat of manufacture. The raw material is there taken by the manufacturer, spun into thread, woven into cloth, bleached and printed, glazed, and finished. It is then repacked, and again placed on the railway and transported once more to Liverpool, when it is re-embarked for Charleston or Savannah, for example. Arriving there, it is again placed on a railway or in a steam-boat, and is transported to the interior of the country, and finally returns to the very place at which it originally grew, and is repurchased by its own producer. Without going into arithmetical details, it will be abundantly apparent how large a proportion of the price thus paid for the manufactured article is to be placed to the account of the transport and commercial expenses. The article has made the circuit of almost half the globe before it has found its way back in its manufactured state.

7. The products of agricultural labour have, in general, great bulk with proportionately small value. The cost of transport has consequently a great influence upon the price of these in the market of consumption. Unless, therefore, this transport can be effected with considerable economy, these products must be consumed on the spot where they are produced.

In the case of many animal and vegetable productions of agriculture, speed of transport is as essential as cheapness, for they will deteriorate and be destroyed by the operation of time alone. Without great perfection, therefore, in the art of transport, objects of this class must necessarily be consumed in the immediate neighbourhood of the place where they are raised. Such are, for example, the products of the dairy, the farm-yard, and the garden.

8. In countries where transport is dear and slow, there consequently arises great disadvantage, not only to the rural, but also to the urban population. While the class of articles just referred to are at a ruinously low price in the rural districts, they are at a ruinously high price in the cities and larger class of towns. In the country, where they exist in superfluity, they fetch comparatively nothing: in the towns, where the supply is immeasurably below the demand, they can only be enjoyed by the affluent.

But if sufficiently cheap and rapid means of transport be provided, these productions find their way easily to the great centres of population in the towns, and the rural population which produces them receives in exchange innumerable articles of use and luxury of which they were before deprived.

9. France, one of the most civilised states of Europe, exhibits a deplorable illustration of this. Notwithstanding the fertility of

her soil, the number, the industry, and intelligence of her population, the products of every description, animal and vegetable, which abound in her territory, yet, from the absence of sufficiently easy means of intercommunication, these advantages have been hitherto almost annihilated. All these productions, in the place where they are raised, can be obtained at a lower price than in most other countries; and yet, in consequence of the cost of transport, they would attain, if brought to the place where they are in demand, a price which would amount to a prohibition on their consumption. From this cause the industry of France has long been to a great extent paralysed.

10. In some cases the price of an article at the place of consumption consists exclusively of the cost of transport. An article has frequently no value in the place where it is found, which nevertheless would have a considerable value transported elsewhere. Numerous instances of this will occur in the case of manures used in agriculture. Every reduction, therefore, which can be made in the cost of the transport of these, will tend in a still greater proportion to lower their price to those who use them.

Cases even occur in which the cost of transport is actually greater than the price paid for an article by the consumer. This, which would seem a paradox, is nevertheless easily explained. An article in a given place may be a nuisance, and its possessor may be willing to pay something for its removal. This article, however, transported to another place, may become eminently useful, and even be the means of stimulating profitable production. The cleansing the common sewers of a city affords a striking example of this. The filth and offal which are removed are a nuisance where they exist, and may even be the cause of pestilence and death. Transported, however, to the fields of the agriculturist, they become the instruments of increased fertility. Cases may be cited where the whole cost of transport will be more than covered by the sum paid for the removal of the nuisance.*

11. Every improvement in the art of transport having a tendency to diminish cost, and augment speed and safety, operates in a variety of ways to stimulate consumption and production, and thereby advance national wealth and prosperity. When the price of an article in the market of consumption is reduced by this cause, the demand for it is increased: 1st, by enabling former consumers to use it more freely and largely; and, 2ndly, by placing it within the reach of other classes of consumers who were before compelled to abstain from it by its dearness. The increase of

* In Aberdeen the streets were swept every day, at an annual cost of 1400*l.*, and the refuse brought in 2000*l.* a-year. In Perth the scavenging cost 1300*l.* per annum, and the manure sold for 1730*l.*

consumption from this cause is generally in a larger ratio than the diminution of price. The number of consumers able and willing to pay one shilling for any proposed article is much more than twice the number who are able and willing to pay two shillings for the same article.

But consumption is also augmented in another way by this diminution of price. The saving effected by consumers who, before the reduction, purchased at the higher price, will now be appropriated to the purchase of other articles of use or enjoyment, and thus other branches of industry are stimulated.

12. The improvements which cheapen transport, necessarily including the expenditure of less labour in effecting it, might seem, at first view, to be attended with injury to the industry employed in the business of transport itself, by throwing out of occupation that portion of labour rendered superfluous by the improvement. But experience shows the result to be the reverse. The diminished cost of transport invariably augments the amount of commerce transacted, and in a much larger ratio than the reduction of cost; so that, in fact, although a less amount of labour is employed in the transport of a given amount of commodities than before, a much larger quantity of labour is necessary by reason of the vast increase of commodities transmitted. The history of the arts supplies innumerable examples of this. When railways were first brought into operation, it was declared, by the opponents of this great improvement (for it had opponents, and violent ones), that not only would an immense amount of human industry connected with the business of land carriage be utterly thrown out of employment, but also that a great quantity of horses would be rendered useless. Experience was not long in supplying a striking proof of the fallacy of this prevision.

13. The moment the first great line of railway was brought into operation between Liverpool and Manchester, the traffic between those places was quadrupled; and it is now well known that the quantity of labour, both human and chevaline, employed in land carriage where railways have been established, has been increased in a vast proportion, instead of being diminished.

In 1846 there were seventy-three stage-coaches or lines of omnibus employed in the transport of passengers to and from the several stations of the North of France Railway, which supplied 176 arrivals and departures, had 5776 places for passengers, and employed daily 979 horses. In the six months ending 31st December, 1846, these coaches transported 486948 passengers.

Improvements in transport which augment the speed, without *injuriously increasing* the expense or diminishing the safety, are *attended with effects* similar to those which follow from cheapness.

14. A part of the cost of transport consists of the interest on the cost of production chargeable for the time elapsed between the departure of the article from the producer and its delivery to the consumer. This element of price is clearly diminished in the exact proportion to the increased speed of transport.

But increased speed of transport also operates beneficially on commerce in another way. Numerous classes of articles of production become deteriorated by time, and many are absolutely destroyed, if not consumed within a certain time. It is evident that such articles admit of transport only when they can reach the consumer in a sufficiently sound state for use; various classes of articles of food come under this condition.

While the Houses of Parliament were occupied with the numerous railway acts which have been brought before them, a great mass of evidence was produced illustrating the advantages which both producer and consumer would obtain by the increased cheapness and expedition of transport which railways would supply. It was shown that the difficulties attending transport by common roads affected, in an injurious manner, the grazier who supplied the markets with veal and lamb. Lambs and calves were generally sent by the road; and when too young to leave the mothers for so long a time as the journey required, the producer was obliged to send the ewes or cows with them for at least a part of the way. This also rendered it impossible to send them to market sufficiently young, which it would have been advantageous to do, that the mothers might feed off earlier.

15. But, independently of this, the animals of every species driven to market on the common roads were proved to suffer so much from the fatigue of the journey, that when they arrived at market their flesh was not in a wholesome state. They were often driven till their feet were sore. Sheep frequently had their feet literally worn off, and were obliged to be sold on the road for what they would fetch. Extensive graziers declared that, in such cases, they would be gainers by a safe and expeditious transport for the animals, "even though it cost double the price paid to the drovers."

Butchers engaged in large business in London proved that the cattle driven to that market from considerable distances sustained so much injury that their value was considerably lessened, owing to the inferior quality of the meat, arising from the animal being slaughtered in a diseased state; that the animal being fatigued and overdriven "became feverish, his looks became not so good, and he lost weight by the length of the journey and the fatigue."

16. It was shown further, that even steam-vessels, when they could be resorted to, did not altogether remove this objection. Cattle arriving from Scotland in steam-vessels are found in London to be

in an unnatural state; "they seem stupified, and in a state suffering from fatigue."

It is not merely the fatigue of travelling which injures the animal, but also the absence from its accustomed pasture. The injury from this cause is more or less, under different circumstances, but always considerable: in order to obviate this, a large portion of the meat supplied to the London market was slaughtered in the country, and came in this state, in winter, from distances round London to the extent of one hundred miles. In warm weather a large quantity of it was spoiled. The transport of calves and lambs from a distance greater than thirty miles is altogether impracticable by common roads, and even from that distance is attended with difficulty and injury.

To convey these and other live cattle from a great distance, not only speed but evenness of motion is indispensable. Now these two requisites cannot be combined by any other means than the application of steam-engines upon a railroad.

The whole of the evidence showed that the supply of animal food to the metropolis was not only defective in quantity, but of unwholesome quality—comparatively, at least, with what it might be, if the tract from which it could be supplied were rendered more extensive.

17. But, forcibly as the evidence bore on this species of agricultural produce, it was still stronger respecting the produce of the dairy and the garden. Milk, cream, and fresh butter, vegetables of every denomination, and certain descriptions of fruit, were usually supplied exclusively from a narrow annulus of soil which circumscribes the skirts of great cities. Every artificial expedient was resorted to, in order to extort from this limited portion of land the necessary supplies for the population. The milk was of a quality so artificial, that we know not whether, in strict propriety of language, the name milk can be at all applied to it. The animals that yielded it were fed, not upon wholesome and natural pasturage, but, in a great degree, on grain and similar articles. It will not be supposed that the milk thus yielded is identical in wholesome and nutritious qualities with the article which could be supplied if a tract of land, of sufficient extent for the pasturage of cattle, was made subservient to the wants of such cities. Add to this that, inferior as must be under such circumstances the quality of the milk, there exist the strongest temptations to the seller who retails it to adulterate it still further before it finds its way to the table of the consumer.

Since the introduction of transport by railways, we see attached *to the fast trains,* morning and afternoon, numerous waggons *loaded with tier over tier* of milk-cans for the supply of the metro-

politan population. Milk is thus brought from pastures at great distances from the cities where it is consumed. In Paris the benefits of this have been very conspicuous.

18. The benefits to farmers and landlords, as well as to the inhabitants of towns, by carrying extensive lines of railroad through populous districts, connecting them with those places from which supplies of food and other necessaries might be obtained, are always considerable. The factitious value which tracts of land immediately surrounding the metropolis and large towns acquire from the proximity of the markets, is thus modified, and a portion of their advantages transferred to the more remote districts; thus equalising the value of agricultural property, and rendering it, in a great measure, independent of local circumstances. The profit of the farmer and the rent of the landlord are augmented by the reduced cost of transport, while the price paid by the consumer is diminished; the advantages of centralisation are realised without incurring the inconvenience of crowding together masses of people within small spaces, and the whole face of the country is brought to the condition, and made to share the opportunities of improvement which are afforded by a metropolis and by towns of the larger class.

19. Steam navigation affords many striking examples of like advantages obtained in the transport of perishable productions.

Pines are now sold in the markets of England which are brought from the West Indies; various sorts of fruits are likewise brought from the countries on the coast of Europe which could not be transported in sailing vessels, as they would not keep during the voyage. Oranges are sent in large quantities from the Havannah to New Orleans and Mobile, in the United States: when they are brought by sailing vessels, a large proportion of the cargo is lost by the destruction and deterioration of the fruit; when sent by steamers, they arrive sound.

The utility of an article often depends on its place. Thus, what is useless at one part of the world will become eminently valuable if transmitted to another. We have already given examples of this in the case of agricultural manures. Others present themselves. Ice at mid-winter in Boston, Halifax, or St. John's, has no value; but this ice, properly packed and embarked, is transmitted to the Havannah or Calcutta, where a price is readily obtained for it which pays with profit the cost of the voyage.

Like all the other effects of improved transport, this reacts and produces collateral benefits. The ships thus enabled to go to Calcutta laden with a cargo which costs nothing and produces a considerable profit, instead of going in ballast, which would be attended with a certain expense, return with cargoes which again

become profitable in the port from which they sailed, and which they could not have brought with profit unless aided by the expedient just mentioned.

20. Important as are improvements in the transport of the products of industry, they are less so than those which facilitate the transport of persons. Here speed becomes of paramount importance. In the case of the products of industry, the time of the transport is represented only by the interest on the cost of production of the article transmitted.

In the case of the transport of persons, the time of transport is represented by the value of the labour of the travellers, and their expenses on the road; and as travellers in general belong to the superior and more intelligent classes their time is proportionally valuable.

21. When cheapness can be sufficiently combined with speed, considerable advantage is gained by the operative classes.

The demand for labour in the several great centres of population varies from time to time, sometimes exceeding, and sometimes falling short of the supply. In the latter case, the operative having little other capital save his bodily strength, is reduced to extreme distress, nay, often even to mendicancy.

In the former case, the producer is compelled to pay an excessive rate of wages, which falls disadvantageously on the articles produced, in the shape of an undue increase of price, and thereby checks consumption. But although the equilibrium between supply and demand in the labour market is liable to be thus deranged, it rarely or never happens that it is subject to the same derangement in all the centres of population. Supply is never in excess everywhere at once, nor is it in all places at once deficient. Improvements in transport, which will render travelling cheap, easy, and expeditious, so as to bring it within the means of the thrifty and industrious operative, will enable labour to shift its place and seek those markets in which the demand is greatest. Thus, the places where the supply is in excess will be relieved, and those where the demand is in excess will be supplied.

22. The extent of soil by which great cities are supplied with perishable articles of food, is necessarily limited by the speed of transport. A ring of country immediately about a great capital, is occupied by market gardens and other establishments for supplying the vast population collected in the city with their commodities. The width of this ring will be determined by the speed with which the articles in question can be transported. It cannot exceed such a *breadth as* will enable the products raised at its extreme limit to *reach the centre* in such a time as may be compatible with their *fitness for use.*

It is evident that any improvement in transport which will double its speed will double the radius of this circle; an improvement which will treble its speed will increase the same radius in a threefold proportion. Now, as the actual area or quantity of soil included within such a radius is augmented, not in the simple ratio of the radius itself, but in the proportion of its square, it follows that a double speed will give a fourfold area of supply, a triple speed a ninefold area of supply, and so on. How great the advantages therefore are, which in this case attend increased speed, are abundantly apparent.

23. So far as relates to the transport of persons, the advantages of increased speed are equally remarkable. The population of a great capital is condensed into a small compass, and, so to speak, heaped together, by the difficulty and inconvenience of passing over long distances. Hence has arisen the densely populated state of great cities like London and Paris. With easy, cheap, and rapid means of locomotion, this tendency, so adverse to physical enjoyment and injurious to health, is proportionally neutralised. Distances practically diminish in the exact ratio of the speed of personal locomotion. And here the same arithmetical proportion is applicable. If the speed by which persons can be transported from place to place be doubled, the same population can, without inconvenience, be spread over four times the area; if the speed be tripled, it may occupy nine times the area, and so on.

Every one who is acquainted with the present habits of the population of London, and with those which prevailed before the establishment of railways, will perceive the practical truth of this observation. It is not now unusual for persons whose place of business is in the centre of the capital, to reside with their families at a distance of from fifteen to twenty miles from that centre. Nevertheless, they are able to arrive at their respective shops, counting-houses, or offices, at an early hour of the morning, and to return without inconvenience to their residence at the usual time in the evening. Hence in all directions round the metropolis in which railways are extended, habitations are multiplied, and a considerable part of the former population of London has been diffused in these quarters. The same will, of course, be applicable to the country which surrounds all other great towns. It is felt at Paris, Brussels, Berlin, Dresden, Vienna, and other capitals of Europe, just in the same proportion in which they are supplied with railway communication.

This principle of diffusion, however, is not confined to the towns only. It extends to an entire country when well intersected by lines of easy, rapid, and cheap communication.

The population, instead of being condensed into masses, is

more uniformly diffused; and the extent of the diffusion which may be thus effected, compatibly with the same degree of intercourse, will be, to use an arithmetical phrase, in the direct proportion of the square of the speed of locomotion.

24. The common average of the speed of diligences in France and other parts of the Continent is two leagues, or about five miles, an hour. The speed of stage-coaches in England, before the establishment of railways, did not average eight miles an hour. According to the principle just explained, it would follow that the same degree of intercourse could be kept up in England in a space of sixty-four square miles, which in France could be maintained only within twenty-five square miles. Since the establishment of railways the average speed upon these lines of communication, on most parts of the Continent and in America, is fifteen miles an hour. By this improvement, so far as it has been carried, as compared with diligences, the area of practical communication, or, what is the same, of the diffusion of the population compatible with a given degree of intercourse, has been augmented in the ratio of the square of five to the square of fifteen; that is, in a ratio of twenty-five to two hundred and twenty-five. In other words, the same degree of intercourse can be maintained by means of the present railways within an area of two hundred and twenty-five square miles, as could be previously maintained by diligences within an area of twenty-five square miles.

But in England, where the average speed of railway transit is much greater, this power of diffusion is proportionally increased. Assuming the average speed on English railways at twenty-five miles an hour, which is less than its actual amount, the power of intercommunication thus obtained will bear to that obtained on the Continent of Europe where railways are in operation, the ratio of the square of twenty-five to the square of fifteen; that is, of six hundred and twenty-five to two hundred and twenty-five, or of twenty-five to nine.

Thus, the English railways afford the same facilities of communication within an area of twenty-five square miles as is afforded by the continental railways within an area of nine square miles; and thus, by augmenting the speed from fifteen to twenty-five miles an hour, the practical convenience to the public is augmented in the ratio of twenty-five to nine, or very nearly as three to one.

25. The importance of good internal communications in military affairs has long been acknowledged. By the possession of such means of transport as may enable a body of troops, with their arms and ammunition, to be transported promptly and rapidly from one part of the country to another, the standing army,

maintained as well for the purposes of order at home as for the defence of the frontiers, may be diminished in proportion to such facilities.

Instead of maintaining garrisons and posts at points of the country within short distances of each other, it will be sufficient to maintain them at such points that they can, at need, be transported with promptitude to any other point that may be desired. In case of invasion, or any foreign attack on the frontier, by good internal communications, the troops quartered throughout the interior can be rapidly transferred and concentrated upon the point attacked.

If, however, such improvements in the art of transport facilitate the means of maintaining order at home and of defence against a foreign enemy, on the one hand, they also happily, on the other, greatly diminish the probability of a necessity for such expedients. "The natural effect of commerce," says Montesquieu, "is to tend to and consolidate peace." Two nations who trade with each other soon become respectively dependent. If one have an interest to buy, the other has an interest to sell, and a multitude of ties, commercial and social, spring out of their mutual wants.

26. Nothing facilitates and developes commercial relations so effectually as cheap and rapid means of intercommunication. When, therefore, all nations shall be found more intimately connected with each other by these means, they will inevitably multiply their exchanges, and general commerce will undergo great extension, mutual interest will awaken moral sympathies, and will lead to political alliances. After having for ages approached each other only for war, peoples will henceforth visit each other for purposes of amity and intelligence, and old antipathies, national and political, which have so long divided and ruined neighbouring states, will speedily vanish.

But if, in spite of this general tendency towards pacific progress and peace, war should occasionally break out, the improved means of intercommunication will aid in bringing it to a prompt close. A single battle will decide the fate of a country, and the longest war will be probably circumscribed within a few months.

27. The advantages of good means of communication in the diffusion of knowledge; and the increase of civilisation by intellectual means, are not less considerable. While the means of intercommunication are slow, difficult, and costly, great cities have a tendency to monopolise intelligence, civilisation, and refinement. There genius and talent are naturally attracted, while the rural districts are left in a comparatively rude and almost barbarous state. With easy and rapid means of locomotion, however, the

best part of the urban population circulates freely through the country. This interfusion improves and civilises the rural population. The highest intelligence will be occasionally found, both in public and in private, diffusing knowledge and science in the remotest villages. We cannot now take up a London journal without observing announcements of men distinguished in the various branches of knowledge and art, visiting the various towns and villages of the provinces, and delivering their lectures on science, and entertainments and exhibitions in the fine arts. So rapid are the communications, that it is frequently announced that this or that professor or artist will, on Monday evening, deliver a lecture or entertainment in Liverpool, on Tuesday in Manchester, on Wednesday in Preston, on Thursday in Halifax, on Friday in Leeds, and so forth.

28. Nor is this all. The aspirations of the present generation after the spread of knowledge and the advancement of mind, unsatisfied with a celerity of transmission so rapid by the railway, which literally has the speed of the wind, has provoked from human invention still greater wonders. The Electric Telegraph for the transmission of intelligence, in the most literal sense of the term, annihilates both space and time. The interval which elapses between the transmission of a message from London and its delivery at Paris, Brussels, or Berlin, provided the line is uninterrupted, is absolutely inappreciable.

This system is now spreading throughout the whole civilised world. The United States of America are overspread with a network of electricity. The President's message delivered at Washington, was transmitted from thence to St. Louis, on the confines of the state of Missouri, a distance of about 1200 miles, in an hour. The news from Europe arriving at Boston by the Cunard steamers, is often transmitted to New Orleans, over almost the entire territory of the United States from north to south, a distance of nearly 2000 miles, in less time than would be necessary to commit it to paper. Even the small delay that now exists arises, not from any imperfection in the instrument of transmission, but merely from the line of electric communication being interrupted from point to point, and transferred from one system of telegraphs to another, at several intermediate stations. After improvements shall remove such delays as these, we shall probably see intelligence conveyed in an instant over a quadrant of the globe.

29. But if we would seek for a striking illustration of the effects of the rapid transmission of intelligence by the combination of all *the various expedients* supplied by science to art, it is in the practice *of Journalism* that we are to look for them, and more especially in

the great enterprises of the London newspapers. The proprietors of a single morning journal are able to maintain agencies, for the transmission of intelligence to the central office in London, in all the principal cities of Europe, besides roving correspondents wherever the prevalence of war, revolution, or any other public event excites a local interest. These various agents or "correspondents" as they are called, not only transmit to the centre of intelligence in London regular despatches by the mails, but also, on occasion of emergency, by special couriers.

These despatches are first received by an agent at Dover, by whom they are forwarded to London by a special messenger. But in cases where intelligence arrives of adequate importance, it is transmitted from the principal continental cities direct to London, in an abridged form, by the electric telegraph, thus anticipating the detailed despatches by many days. Within two hours of its arrival the intelligence is in the hands of the London public.

That portion of the journal intended for the provinces is sent to press at 3 A.M.; and by the activity of the editors, reporters, and compositors, all of whom work during the night, it includes not only the detailed reports of the Houses of Parliament, which often sit to a late hour in the morning, but also the foreign news, as above explained, by electric telegraph. This earliest impression is printed and delivered to the newsvenders, in sufficient time to be despatched to the provinces by the early railway trains, and it is thus delivered at all the stations along the road.

The part of the impression intended for London circulation is worked off and delivered later.

Thus we see that, by these combinations of enterprise, intellectual and material, the intelligence which arrives in London at 3 A.M., is written, composed, printed, and distributed within a radius of one hundred miles round London, and in the hands of the population before their customary hour of breakfast.

Even before the present improved methods of transport were brought into operation, wonders in this way were effected.

Thus, in some cases where debates of adequate public interest took place in Parliament in the evening, the evening mails (for there were then no other) carried to the provinces the first part of an important speech, reported and printed before the remaining part was spoken. Thus it was related that the commencement of Mr. (since Lord) Brougham's celebrated speech on the reform of the laws was read at tea-tables twenty miles from London before he had pronounced the peroration.

Few of the numerous readers of newspapers have the least idea of the immense commercial, social, and intellectual powers wielded,

and benefits conferred, by these daily publications, a large portion of which influence is to be ascribed to the cheapness, promptitude, and rapidity with which they are transmitted from the capital to all parts of the country.

It is well known that the average number of copies of the most widely circulating London journal, which are daily issued, amounts at present to more than forty thousand. Each of these forty thousand copies, according to common estimation, passes under the eyes, upon an average, of at least ten persons. Thus we have four hundred thousand daily readers of one organ of information and intelligence. But the effects do not end there. These four hundred thousand *readers*, long before the globe completes a revolution on its axis, become four hundred thousand *talkers*, and have vastly more than four hundred thousand *hearers*. Thus they spread more widely by the ear the information, the arguments, and the opinions they have received through the eye. We shall certainly not be overstating the result if we assume, that this influence of a single journal, directly and indirectly, reaches daily a million of persons.

LOCOMOTION AND TRANSPORT,

THEIR INFLUENCE AND PROGRESS.

CHAPTER II.

RETROSPECT OF THE PROGRESS OF TRANSPORT.

1. Of the first construction and improvement of roads and carriages.—2. Roads do not exist in more than two-sevenths of the inhabited parts of the globe.—3. Roman and Egyptian roads.—4. Roads constructed by order of Semiramis.—5. Internal communication in ancient Greece.—6. Roads of the Phœnicians and Carthaginians.—7. Roman military roads.—8. Commercial intercourse during the middle ages.—9. Influences of the crusades on the art of transport.—10. Roads and intercommunication on the Continent to the middle of the seventeenth century.—11. System of roads projected by Napoleon.—12. Improvement in internal communication after the peace of 1815, roads of France.—13. First roads in England, those made by the Romans.—14. Watling Street, Ermine Street, Fosse-way and Ikenald.—15. First attempts to improve roads in Great Britain in reign of Charles the Second.—16. Transport in Scotland to the middle of the eighteenth century.—17. Slowness of travelling in Scotland.—18. Arthur Young's account of the roads in England in 1770.—19. Comparison between cost and speed of former and present modes of transport.—20. Origin of railways in England.—21. Their immediate effects.—22. Progress of the construction.—23. Their extent in *1852.—24. Capital* absorbed by them.—25. Labour *employed by them.*

LOCOMOTION AND TRANSPORT.

1. In the first attempts at an interchange of the products of industry, which mark the incipient commerce of a people emerging from barbarism, human labour and the strength of the inferior animals, applied in the most rude and direct manner to transport, are all the means brought into play. The pedlar and the pack-horse perform all the operations of interchange which take place in an infant society. Pathways are formed over the natural surface of the ground, in a course more or less direct, between village and village. The beds of streams following, by the laws of physics, the lowest levels, serve as the first indication to the traveller how to avoid steep acclivities, and, by deviating from the most direct and shortest course, to obtain his object with a diminished amount of labour.

As industry is stimulated and becomes more productive, invention is brought more largely into play, and these rude expedients are improved. Wheel carriages are invented, but the earliest theatre of their operations is the immediate surface of the soil from which the products of agriculture are raised. They are used to gather and transport these to a place where they may be sheltered and secured.

But to enable wheel carriages to serve as the means of transport between places more or less distant, the former horse-paths are insufficient. A more uniform and level surface, and a harder substratum, become indispensable. In a word, a Road, constructed with more or less perfection, is necessary.

These roads, at first extremely rude and inartificial, and rendered barely smooth and hard enough for the little commerce of an infant people, are gradually improved. The carriages, also, which serve as the means of transport undergo like improvement, until, after a series of ages, that astonishing instrument of commerce, the modern road, results, which is carried on an artificial causeway, and reduced, at an enormous expense, to a nearly level surface by means of vast excavations, extensive embankments, bridges, viaducts, tunnels, and other expedients supplied by the skill and ingenuity of the engineer.

Between the pack-horse, used in the first stages of growing commerce, and such a road with its artificial carriages, there is a prodigious distance. The first step, from the pack-horse to the common two-wheel cart, was, in itself, a great advance.

It is calculated that a horse of average force, working for eight or ten hours a day, cannot transport on his back more than two hundredweight, and that he can carry this at the rate of only *twenty-five* miles a day over an average level country. The *same horse, working* in a two-wheel cart, will carry through the *same distance* per day twenty hundredweight, exclusive of the

weight of the cart. By this simple expedient, therefore, the art of transport was improved in the ratio of one to ten; in other words, the transport which before was effected at the cost of ten pounds, was, with this expedient, reduced to the cost of one pound.

2. The adoption of expedients for the maintenance of commerce so obvious as roads, would seem to be inevitable among a people who are not actually in a state of barbarism. Nevertheless, we find that not only was the construction of good roads for commercial purposes of comparatively recent date, but that, even at the present day, a very large portion of that part of the world called civilised, is unprovided with them. With the exception of certain parts of Europe, the French colony of Algeria, and the United States, the entire surface of the world is still without this means of intercourse.

It is calculated that, of the entire inhabited part of the globe, roads do not exist in more than *two-sevenths*. The extensive empire of Russia, with the exception of one or two main communications, such as that between Petersburg and Moscow, is without them. In general, the only practicable communications through this vast territory are effected in winter on the surface of the frozen snow by sledges. On the return of summer, when the snow has disappeared, the communications become extremely difficult, slow, and expensive. Spain is scarcely better supplied with roads than Russia, nor do we find much improvement in the practice of transport in Italy. Until recently, Corsica possessed no communications of this sort; horses and mules were the common means of communication and interchange in that island until the French government constructed some roads.

3. The roads constructed by the Romans and Egyptians will probably be referred to as instances of an early advance in this art. But these great monuments of antiquity, though serving incidentally, to some extent, as means of commerce, were constructed for exclusively military purposes.

4. The most ancient roads which are recorded in history, are those constructed by order of Semiramis, throughout the extent of her empire. It would seem, however, that the commerce of that day did not find these communications suitable to its objects; for it is certain that, at the epoch at which Tyre and Carthage were signalised for their enterprise, their commerce was almost exclusively carried on by the coasting navigation of the Mediterranean.

5. Notwithstanding the advanced stage to which civilisation had arrived in *Greece, the means* of internal communication in that *country remained in a state of* great imperfection. This may in

part be explained by the multitude of small states which formed that confederation, by their conflicting interests, and their want of any moral or social sympathies. The common sentiment of nationality slumbered, except when it was awakened by the strong stimulus of foreign attack. The intercourse between one centre of population and another was then very restrained, and although the public ways were placed under the protection of the gods, and the direction of the most considerable men of the respective states, they were suffered to fall into neglect. The exigencies of internal commerce were never sufficiently pressing to excite the people to contribute to the maintenance of good means of intercommunication and exchange.

6. The earliest roads which were really rendered conducive to the purposes of commerce, on any considerable scale, were those constructed by the Phenicians and Carthaginians. To the latter is ascribed, by Isidore, the invention of paved roads.

7. When imperial Rome attained the meridian of her power, and her empire extended over a large portion of Europe and Asia, colossal enterprises were entered upon for the construction of vast lines of communication, extending over the immensity of her territory. These roads, however, like those of the Egyptians, were constructed without the slightest view to commercial objects. It concerned imperial Rome but little, that her provinces should be united by commercial or social interests. What she looked to was to be enabled to convey with celerity her powerful legions at all times from one extremity of her dominions to another. With this purpose, she availed herself of her vast resources to construct those military roads, intersecting her territory, the remains of which have excited the admiration of succeeding generations.

The first of these great monuments of the enterprise and art of the Roman people were those so well known by the names of the Via Appia, the Via Aurelia, and the Via Flaminia. Under Julius Caesar, communications were made by paved roads between the capital of the empire and all the chief towns. During the last African war, a paved road was constructed from Spain, through Gaul, to the Alps. Subsequently similar lines of communication were carried through Savoy, Dauphiné, Provence, through Germany, through a part of Spain, through Gaul, and even to Constantinople.

Asia Minor, Hungary, and Macedonia were overspread with similar lines of communication, which were carried to the mouths of the Danube. Nor was this vast enterprise obstructed by the intervention of seas. The great lines which terminated on the shores of continental Europe were continued at the nearest points of the neighbouring islands and continents. Thus, Sicily, Corsica,

Sardinia, and England, and even Africa and Asia, were intersected and penetrated by roads, forming the continuation of the great European system.

These colossal works were not paths rudely prepared for the action of the feet of horses and the wheels of carriages, by merely removing the natural asperities from the surface of the soil. They were constructed, on the contrary, on principles in some respects as sound and scientific as those which modern engineering has supplied. Where the exigencies of the country required it, forests were felled, mountains excavated, hills levelled, valleys filled up, chasms and rivers bestridden by bridges, and marshes drained, to an extent which would suffer little by comparison with the operations of our great road-makers of modern times.

On the fall of the Empire, these means of communication, instead of subserving the purposes of the commerce of the people through whose territory they were carried, were, for the most part, destroyed. When the barbarians conquered Rome, and a multitude of states were formed from its ruins, the victors shut themselves up and fortified themselves in these several states, as an army does in a citadel; and, far from constructing new roads, they destroyed those which had already existed, as a town threatened with siege breaks those communications by which the enemy may approach it.

8. From this epoch through a long series of ages, the nations of Europe, animated only by a spirit of reciprocal antagonism, thought of nothing but war, and entered each other's territories only for the purposes of conflict. The history of the intercommunications of nations during the middle ages is only a history of their wars.

When Europe emerged from this state, and when commerce began to force itself into life, its operations were in a great measure monopolised by Jewish and Lombard merchants, who carried them on subject to the greatest difficulty and danger.

The provincial nobles and lords of the soil, through whose possessions the merchant necessarily passed in carrying on the internal commerce of the country, were nothing better than highway robbers. They issued with their bands from their castles and arrested the travelling merchant, stripping him of the goods which he carried for sale.

The sovereigns of France endeavoured in vain, by penal enactments, to check this enormous evil. Dagobert I. established a sort of code to regulate the public communications through his dominions, and decreed heavy fines against such provincial lords as might *obstruct the freedom* of communication, by *interrupting or plundering travellers.* These decrees, however, remained a

dead letter, no adequate power in the state being able to carry them into practical effect.

Under the successors of Charlemagne, this abuse, which it was found impossible to repress, was, in some measure, recognised and regularised. Tolls of limited amount were allowed to be exacted by the local proprietors from those who passed through the provinces for purposes of trade, on the condition that such travellers or merchants should be otherwise unmolested.

The prevalence of all these vexatious impediments soon rendered intercommunication by land almost impracticable. The roads, such as they were, became accordingly deserted, and were suffered to fall into utter disrepair. During a series of ages, internal communication and internal commerce became almost suspended; a journey even of a few leagues being regarded as a most serious and dangerous undertaking.

9. The Crusades had a favourable influence on the art of transport. The population of Western and Northern Europe became by them acquainted with the productions and arts of the East. New desires were excited and new wants created. Commerce was thus stimulated, and greater facility of intercourse becoming necessary, governments were forced to adopt expedients for the security of the traveller.

The same difficulties and dangers did not, however, affect navigation. We find this art developed in a much higher degree than that of internal commerce. Hence arose the disproportionate commercial opulence of maritime people. The British, the Dutch, and the Portuguese rose into immense commercial importance, as well as the Genoese, the Tuscans, and the Venetians.

10. Even so late as the middle of the seventeenth century, the roads throughout the Continent continued in a condition which rendered travelling almost impracticable.

They are described by writers of this epoch as being absolute sloughs. Madame de Sevigny, writing in 1672, says, that a journey from Paris to Marseilles, which by the common roads of the present day is effected in less than sixty hours, required a whole month.

Besides the material obstacles opposed to the growth of internal commerce on the Continent by the want of roads in sufficient number, and the miserable state of those which did exist, other impediments were created and difficulties interposed by innumerable fiscal exactions, to which the trader was exposed, not only in *passing the confines* of different states, but even in going from *province to province* in the same state, and in passing through

almost every town and village. Hence the cost of every commodity was enormously enhanced, even at short distances from the place of its production.

11. The disorganisation of society and the destruction of the institutions of feudalism which followed the French Revolution of 1789, caused some improvement in the means of internal commerce in Europe, and would have caused a much greater development in this instrument of civilisation, but for the wars which immediately succeeded that political catastrophe, and which only terminated with the battle of Waterloo.

Indeed Napoleon, conscious of the vast importance of a more complete system of roads, had actually projected one, which he intended to spread over Europe. His fall, however, intercepted the realisation of this magnificent design, and the *Simplon* remains as the only monument of his glory in this department of art.

After the re-establishment of peace, the nations of Europe, directing their activity to industry and commerce, soon became impressed with the necessity of effecting a great improvement in the means of internal communication. Western Europe, accordingly, soon began to be covered with roads and canals. The obstructions arising from fiscal causes, if not removed, were greatly diminished.

The advance made by France especially in this department, is deserving of notice. That country possesses at present four or five times the extent of roads which were practicable under the Empire; a sum of nearly four millions sterling was, until lately, expended annually upon the completion and maintenance of these great lines of communication.

The roads of France consist of three classes; the first, until the late revolution, were called *royal roads*, and are now called *national roads*. These are the great arteries of communication carried from one chief town to another throughout the territory, and being used indifferently, or nearly so, by the whole population, are constructed and maintained at the general expense of the nation. The second class are *departmental roads*, or what would be called in England *county roads*. These are chiefly the branches running into the royal roads, by which the local interests of the departments are served, and are accordingly maintained at the expense of the departments. Finally, the third class is called *vicinal roads*, which would correspond to our *parish roads*.

The rate at which these improved communications have contributed to augment the internal commerce and national wealth, may be estimated in some degree from the statistical results which have been published. In 1810, the various stage-coach establish-

ments in Paris transported each day from the capital into the departments, two hundred and twenty passengers, and twenty-one tons of merchandise. Before the establishment of railways, they transported nearly one thousand passengers and forty-five tons of merchandise. Thus the passengers were augmented in a fourfold, and the merchandise in a twofold proportion.

12. In 1815, the length of roads in operation in France was as follows: there were three thousand leagues of royal roads, and two thousand leagues of departmental roads. In 1829, there were four thousand two hundred and five leagues of royal roads, and three thousand leagues of departmental roads. In 1844, there were eight thousand six hundred and twenty-eight leagues of royal roads, and nine thousand one hundred and forty-six leagues of departmental roads, independently of twelve thousand leagues of vicinal roads. Thus, it appears that between 1815 and 1844, the total length of roads of the first and second classes was augmented from five thousand leagues to nearly eighteen thousand, or in the proportion of three and a half to one.

13. Although the practice of road-making in England attained a certain degree of perfection at a much earlier period than in other parts of Europe, and the United Kingdom was overspread with a noble network of internal communications, while continental Europe remained in a comparatively barbarous condition, the art of transport nevertheless, even in England, remained for a long series of ages incalculably behind what would seem to be the commercial wants of the population.

The first English roads of artificial construction were those made by the Romans, while England was a province of that empire. The island was then intersected by two grand trunk roads running at right angles to each other, the one from north to south, and the other from east to west.

These main lines were supplied with various branches, extending in every direction which the conquerors found it expedient to render accessible to their armies.

14. The Roman road called *Watling Street* commenced from Richborough, in Kent, the ancient Rutupial, and, passing through London, was carried in a north-westerly direction to Chester. The road called *Ermine Street* commenced from London, and, passing through Lincoln, was carried thence through Carlisle into Scotland. The road called the *Fosse-way* passed through Bath in a direction N.E., and terminated in the Ermine Street. The road called *Ikenald* extended from Norwich in a southern direction to Dorsetshire.

But these great works, at the date of their construction, exceeded *the wants of* the population, who, unconscious of their

advantage, allowed them to fall into neglect and disrepair. Nor were any new roads in other or better directions constructed. For a succession of ages the little intercourse that was maintained between the various parts of Great Britain was effected almost exclusively by rude footpaths, traversed by pedestrians, or at best by horses.

These were carried over the natural surface of the ground, generally in straight directions, from one place to another. Hills were surmounted, valleys crossed, and rivers forded by these rude agents of transport, in the same manner as the savages and settlers of the backwoods of America or the slopes of the Rocky Mountains now communicate with each other.

15. The first important attempt made to improve the communications of Great Britain took place in the reign of Charles II. In the sixteenth year of the reign of that monarch was established the first turnpike road where toll was taken, which intersected the counties of Hertford, Cambridge, and Huntingdon. It long remained, however, an isolated line of communication; and it was little more than a century ago that any extensive or effectual attempts were made, of a general character, to construct a good system of roads through the country.

16. Until the middle of the eighteenth century, most of the merchandise which was conveyed from place to place in Scotland was transported on pack-horses. Oatmeal, coals, turf, and even hay and straw, were carried in this manner through short distances; but when it was necessary to carry merchandise between distant places, a cart was used, a horse not being able to transport on his back a sufficient quantity of goods to pay the cost of the journey.

17. The time required by the common carriers to complete their journey seems, when compared with our present standard of speed, quite incredible. Thus, it is recorded that the carrier between Selkirk and Edinburgh, a distance of thirty-eight miles, required a fortnight for his journey, going and returning. The road lay chiefly along the bottom of the district called *Gala-water*, the bed of the stream, when not flooded, being the ground chosen as the most level and easy to travel on.

In 1678, a contract was made to establish a coach for passengers between Edinburgh and Glasgow, a distance of forty-four miles. This coach was drawn by six horses, and the journey between the two places, to and fro, was completed in six days. Even so recently as the year 1750, the stage-coach from Edinburgh to Glasgow took thirty-six hours to make the journey. In 1849, the same *journey was made, by* a route three miles longer, in one *hour and a half!*

In the year 1763 there was but one stage-coach between Edinburgh and London. This started once a month from each of these cities. It took a fortnight to perform the journey. At the same epoch the journey between London and York required four days.

In 1835 there were seven coaches started daily between London and Edinburgh, which performed the journey in less than forty-eight hours. In 1849, the same journey was performed by railway in twelve hours!

In 1763, the number of passengers conveyed by the coaches between London and Edinburgh could not have exceeded about twenty-five *monthly*, and by all means of conveyance whatever did not exceed fifty. In 1835 the coaches alone conveyed between these two capitals about one hundred and forty passengers *daily*, or four thousand monthly. But besides these, several steam-ships, of enormous magnitude, sailed weekly between the two places, supplying all the accommodation and luxury of floating hotels, and completing the voyage at the same rate as the coaches, in less than forty-eight hours.

As these steam-ships conveyed at least as many passengers as the coaches, we may estimate the actual number of passengers transported between the two places monthly at eight thousand. Thus the intercourse between London and Edinburgh in 1835 was one hundred and sixty times greater than in 1763.

At present the intercourse is increased in a much higher ratio, by the improved facility and greater cheapness of railway transport.

18. Arthur Young, who travelled in Lancashire about the year 1770, has left us in his Tour the following account of the state of the roads at that time. "I know not," he says, "in the whole range of language, terms sufficiently expressive to describe this infernal road. Let me most seriously caution all travellers who may accidentally propose to travel this terrible country to avoid it as they would the devil, for a thousand to one they break their necks or their limbs by overthrows or breakings down. They will here meet with ruts, which I actually measured, four feet deep, and floating with mud, only from a wet summer. What, therefore, must it be after a winter? The only mending it receives is tumbling in some loose stones, which serve no other purpose than jolting a carriage in the most intolerable manner. These are not merely opinions, but facts; for I actually passed three carts broken down in these eighteen miles of execrable memory."

And again he says (speaking of a turnpike road near Warrington, *now superseded* by the Grand Junction Railway,) "This is a

paved road, most infamously bad. Any person would imagine the people of the country had made it with a view to immediate destruction! for the breadth is only sufficient for one carriage; consequently it is cut at once into ruts; and you may easily conceive what a break-down, dislocating road, ruts cut through a pavement must be."

Nor was the state of the roads in other parts of the north of England better. He says of a road near Newcastle, now superseded by a railway, "A more dreadful road cannot be imagined. I was obliged to hire two men at one place to support my chaise from overturning. Let me persuade all travellers to avoid this terrible country, which must either dislocate their bones with broken pavements, or bury them in muddy sand. It is only bad management that can occasion such very miserable roads in a country so abounding with towns, trade, and manufactures."

Now, it so happens that the precise ground over which Mr. Young travelled in this manner less than eighty years ago is at present literally reticulated with railways, upon which tens of thousands of passengers are daily transported, at a speed varying from thirty to fifty miles an hour, in carriages affording no more inconvenience or discomfort than Mr. Young suffered in 1770, when reposing in his drawing-room in his arm-chair.

19. Until the close of the last century, the internal transport of goods in England was performed by waggon, and was not only intolerably slow, but so expensive as to exclude every object except manufactured articles, and such as, being of light weight and small bulk in proportion to their value, would allow of a high rate of transport. Thus the charge for carriage by waggon from London to Leeds was at the rate of 13*l.* a ton, being 13½*d.* per ton per mile. Between Liverpool and Manchester it was forty shillings a ton, or 15*d.* per ton per mile. Heavy articles, such as coals and other materials, could only be available for commerce where their position favoured transport by sea, and, consequently, many of the richest districts of the kingdom remained unproductive, awaiting the tardy advancement of the art of transport. Coals are now carried upon railways at a penny per ton per mile, and, in some places, at even a lower rate. Merchandise, such as that mentioned above, which was transported in 1763 at from 14*d.* to 15*d.* per mile, is now carried at from 3*d.* to 4*d.*, while those sorts which are heavier in proportion to their bulk are transported at 2½*d.* per ton per mile.

But *this is not all: the* waggon transport formerly practised *was limited to a speed* which in its most improved state did not

exceed twenty-four miles a day, while the present transport by railway is effected at the rate of from twelve to fourteen miles an hour.

20. When we look back upon the state in which every part of the civilised world was placed in relation to this vital element of social and commercial progress, this standard and test, as it may be justly called, of civilisation at an epoch so recent as the first year of the present century, and compare it with the present condition not of England only, but of Europe and North America, we cannot fail to be struck with the incalculable amount of benefit to the human race that must result from the extraordinary energy with which the discoveries and resources of science have been applied to the improvement of this instrument of civilisation within the brief interval of twenty-four years, for it is not more since the date of the commencement of railway transport in this country which took the lead in that, as in so many other improvements in the arts of life.

21. In 1830, the first railway for general traffic in passengers and goods between Liverpool and Manchester was opened; and immediately, of the thirty stage-coaches which had previously run daily between Liverpool and Manchester, one only remained on the road; and that was supported solely by passengers to intermediate places not lying in the direction of the railway.

The comparatively low fares and extraordinary expedition offered by the railway had the effect which might have been expected. Previously, the number of travellers daily, by the coaches, was about five hundred; it was immediately augmented above three-fold. Sixteen hundred passengers per day passed between these towns. If the traffic in passengers exceeded all anticipation, the transport of goods, on the contrary, fell short of what was expected. The canal lowered its tariff to the level of the railway charges and increased its speed and its attention to the accommodation of customers. The canal, moreover, winding through Manchester, washed the walls of the warehouses of the merchants and manufacturers. At the other end it communicated directly with the Liverpool docks. The goods were therefore received directly from the ship, and delivered directly to the warehouse, or *vice versâ;* without the cost, delay, and inconvenience of intermediate transhipment and cartage. These considerations went far to counterbalance the superior speed of the railway transit for goods; yet, notwithstanding this inconvenience and obstruction, the company soon found themselves carriers of merchandise at the rate of a thousand tons per day.

Thus, the problem of the rapid transport of passengers by steam

on railways was solved in 1830, and the profitable character of the enterprise soon became apparent. Dividends of 10 per cent. were declared, and the shares were greedily bought up at 120 per cent. premium. Then followed in rapid succession those results which must necessarily have ensued. Other lines of railway, connecting the chief centres of population and industry with the metropolis, and with each other, were projected. In the four years which elapsed from 1832 to 1836, about 450 miles of railway were completed, and 350 miles were in progress of construction.

22. From 1836 to the present time the construction of these great lines of intercommunication in the United Kingdom has proceeded at a rate of progress of which no previous example has ever been recorded in the history of the industrial arts in any country. From the official reports presented to Parliament, it appears that the whole extent of railway communication open for traffic in the United Kingdom at the end of 1852 was 7336 miles, which were distributed in the different portions of the kingdom in the following proportions:—

In England and Wales	5650 miles.
In Scotland	978
In Ireland	708
Total in the United Kingdom . .	7336 miles open for public traffic.

It further appears from these reports that, at the close of 1852, the legislature had authorised the construction of a total length of railway (including the above 7336 miles) amounting to 12561 miles, of which 676 miles had been abandoned by the companies which had originally undertaken them. Thus the account of the total amount authorised by Parliament, to the end of 1852, stood thus:—

Constructed and in operation. . .	7336 miles.
In progress or intended to be commenced	4549
Abandoned	676
	12561 miles.

23. The following table, taken from the report of the Committee of the Privy Council, dated August, 1853, will exhibit the rate at which the railway projects were sanctioned by Parliament, and the rate at which their execution has progressed up to the end of 1852:—

TABLE showing the Proportion of Railways authorised previous to the end of 1843, and in each succeeding Year, opened for Traffic during each Year, and the proportion remaining to be completed at the end of 1852; also, showing the Total Length of Railway opened for Traffic in each Year since 1843.

—		LENGTH OF LINE OPENED.										Total Length of Line opened to December, 1852.	Length of Line authorised at end of 1843 and during each subsequent year.	Decrease by Abandonment, Deviation, &c., under authority of subsequent Acts.	Length of Line after Reductions made in consequence of Abandonment, Deviation, &c., under the authority of Acts passed subsequent to 1843.	Length of Line remaining to be made.
		Previously to December, 1843.	During 1844.	During 1845.	During 1846.	During 1847.	During 1848.	During 1849.	During 1850.	During 1851.	During 1852.					
Of Lines authorised previously to December, 1843		2036	204	131	16	2	1	..	..	..	..	2390	2390	..	2390	..
Of Lines authorised in	1844	..	..	159	366	142	118	3	4	..	..	792	805	..	805	13
	1845	..	..	6	224	573	604	311	213	65	106	2102	2700	33	2667	565
	1846	..	..	..	..	84	403	501	379	122	288	1777	4538	478	4060	2283
	1847	..	..	..	..	2	56	45	26	71	10	210	1354	160	1194	984
	1848	..	..	..	..	..	..	7	..	7	16	30	371	5	366	336
	1849	..	..	..	..	..	..	2	1	..	..	3	16	..	16	13
	1850	..	..	..	..	..	..	..	2	4	..	6	8	..	8	2
	1851	..	..	..	..	..	..	..	..	..	15	15	135	..	135	120
	1852	..	..	..	..	..	..	..	..	..	11	11	244	..	244	233
Total		2036	204	296	606	803	1182	869	625	269	446	7336	12561	676	11885	4549

24. Nothing in the progressive development of this vast national enterprise is more surprising than the amount of capital raised and expended upon it, and the rapidity and facility with which it was obtained.

The following statement, also taken from the official reports, will illustrate this:—

Total capital raised by shares and loans up to the end of 1848.	£200,173058
Total capital similarly raised in 1849. . .	29,574720
Ditto. . . 1850. . .	10,522967
Ditto. . . . 1851. . .	7,970151
Total capital raised up to the end of 1851	£248,240896

Of the sum of 248 millions, which had been expended before the 1st January, 1852, a part had been absorbed by the lines which were in process of construction, but had not yet been opened. Against this, however, there remained an amount of capital still to be expended on the lines already open. On most of the more recently opened railways, the stations were still incomplete; in some cases, depots, workshops, and other permanent buildings had not even been commenced. The full complement of the locomotive and rolling stock had not been provided. In the absence of exact data then, if these latter expenses be placed against the former, the entire capital of 248 millions may be placed to the account of 7336 miles open for traffic; which would give an average expense of construction, including the locomotive and carrying stock, and the workshops and depots for its repair, &c., of 33840*l.* per running mile.

25. The extent to which these enterprises employed the industry of the country may be judged from the following results of the reports:—

It appears that in 1848 a quarter of a million of persons were employed on the railways of the United Kingdom; and if it be considered that each of these must have contributed to the support, on an average, of one or more other persons, it will follow, that this vast enterprise must have, at that epoch, supplied means of living to at least two per cent. of the entire population of these countries.

It further appears that, on the 30th June, 1852, there were employed

On the railways open for traffic	67601
On the railways in progress of construction . . .	35935
	103536

It follows, therefore, that from 1848, to June, 1852, about

150000 persons have been dismissed from the direct employment of the railway companies, and who must now be obtaining support from other occupations. It is, however, certain that a large increase of the demand for labour has been produced by the creation and operation of railway traffic, such as that which arises and must arise from the establishment of founderies, carriage, and engine building, and other branches of railway business, not only in the United Kingdom, but in other countries which are to a great extent supplied by British industry.

We shall on another occasion notice the progress of locomotion by railway in other countries.

TELESCOPIC VIEW OF THE REGION OF THE MOON SURROUNDING THE CIRCULAR MOUNTAIN CHAIN CALLED TYCHO, MEASURING ABOUT 375 MILES NORTH AND SOUTH, AND ABOUT 200 MILES EAST AND WEST.

THE MOON.

1. Interest with which the moon is regarded, and influences with which it has been invested by the popular mind.—2. Its distance.—3. Its orbit.—4. Its magnitude.—5. Its rotation.—6. Conjunction.—7. Quadrature.—8. Opposition.—9-11. Tests of an atmosphere.—12-13. None exists on the moon.—14. No liquids.—15. No diffusion of solar light.—16. Appearance of earth seen from moon.—17. It would have belts.—18. Geographical features and its rotation would be visible through the clouds.—19. Moonlight neither warm nor cold.—20. Moon's physical condition.—21. Thickly covered with mountains.—22. Selenographical discoveries of Beer and Mädler.—23. Vast extent and diameter of the lunar mountains.—24. Circular chains.—25. Description of Tycho. — 26. Heights of lunar mountains.—27. Observations of Lord Rosse.—28. Moon not inhabited.

1. Estimated merely by its magnitude, the moon is among the most inconsiderable of the bodies which compose the Solar System. It has not, as will presently appear, even that interest which must attach to a globe adapted for the habitation of organised races, analogous to those for whose dwelling the earth has been appropriated. Nevertheless it has ever been regarded by mankind with sentiments of profound and peculiar interest, and has been invested by the popular mind with various influences, affecting not only the physical condition of the globe, but also directly connected with the organised world. It has therefore been as much an object of popular superstition as of scientific observation. These circumstances are doubtless owing in some degree to its striking appearance in the firmament, to the various and rapid succession of changes of apparent form to which it is subject, and above all to its proximity to, and close alliance with our planet. We propose on the present occasion to give a general account of its motion, magnitude, and physical condition; and to explain more particularly those circumstances which lead to the conclusion that, unlike the planets, the moon presents none of the analogies to the earth which would render it at all probable or even possible that it can be a habitable world.

2. It has been ascertained, that its distance is very little less than 240000 miles; and since the semidiameter of the earth is 4000 miles, it follows that the moon's distance is about sixty semidiameters of the earth. The method of ascertaining this distance differs in nothing that is essential, from that by which a common surveyor ascertains the distance of an object on the earth which is inaccessible to him.

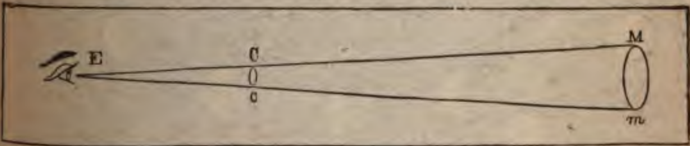
3. Now the least reflection will render it apparent that the moon must move round the earth, in a path which cannot differ much from a circle of which the earth is the centre. This follows from the fact with which every one is familiar, that its apparent magnitude is always nearly the same. It is, therefore, always at the same or nearly the same distance from the observer. The earth must consequently be placed in the centre of its path, and that path must be nearly a circle.

4. When the distance of a visible object is determined, its magnitude may easily be ascertained by comparing it with any other object of known magnitude at a known distance. Let us take, for example, a halfpenny, which measures about an inch in diameter, and let it be placed between the eye and the moon. It will be found on the first trial that the coin will appear larger *than the moon; it* will, in fact, completely conceal the moon from *the eye, and produce* what may be termed a total eclipse of that *luminary*. Let the coin be moved however further from the eye,

and it will apparently diminish in size as its distance is increased. Let it be removed until it becomes equal in apparent magnitude to the moon, so that it will exactly cover the moon, and neither more nor less. If its distance be then measured, it will be found to be about 120 inches, or 240 half inches. But it is known that the distance of the moon is about 240000 miles, and consequently it follows in this case, that 1000 miles in the moon's distance is exactly what half an inch is in the coin's distance. Now under the circumstances here supposed, the coin and the moon are similar objects of equal apparent magnitude. In fact the coin is another moon on a smaller *scale*, and we may use the coin to measure the moon's distance, provided we know the *scale*, exactly as we use the space upon a map of any known scale to measure a country. But it has been just stated that the *scale* is in this case half an inch to 1000 miles; since, then, the coin measures two half inches in diameter, the moon must measure 2000 miles in diameter. The moon is then a globe whose diameter is about one-fourth of that of the earth.

This may be rendered still more clear by reference to the annexed diagram (fig. 1), where E is the eye, C the coin, and M the moon. It will be evident on mere inspection, that the triangle formed by the distance EC of the coin from the eye, and the diameter Cc of the coin, is similar to the triangle formed by the distance EM of the moon from the eye and the diameter M*m* of the moon, and that consequently the proportion of EC to Cc is exactly the same as that of EM to M*m*. But as has just been stated, it is found that when Cc exactly covers the moon, and neither more nor less than covers it, EC is 120 times Cc. It follows, therefore, that EM is 120 times M*m*. But since it has been ascertained that EM is 240000 miles, that is 120 times 2000 miles, it follows that M*m* is 2000 miles.

Fig. 1.



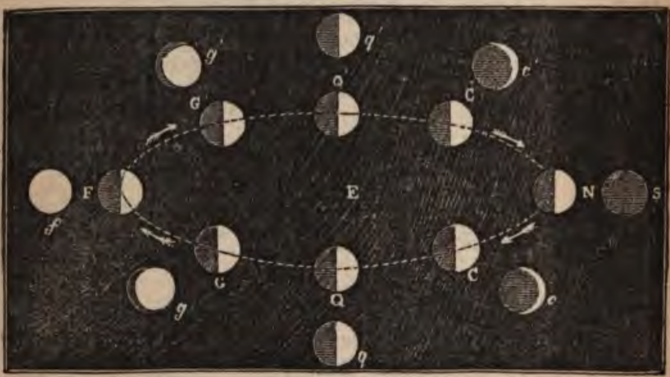
5. While the moon moves around the earth, we find by observations of its appearance, that the same hemisphere is always turned toward us. We recognise this fact by observing that the same marks always remain in the same place upon it. Now, in order that a globe which revolves around a centre should turn continually *the same hemisphere* toward that centre, it is necessary that

it should make one revolution upon its axis in the time it takes so to revolve. For let us suppose that, in any one position, it has the centre round which it revolves north of it, the hemisphere turned toward the centre is turned toward the north. After it makes a quarter of a revolution, the centre is to the west of it, and the hemisphere which was previously turned to the north must now be turned to the west. After it has made another quarter of a revolution the centre will be south of it, and it must be now to the south. In the same manner, after another quarter of a revolution, it must be turned to the east. As the same hemisphere is successively turned to all the points of the compass in one revolution, it is evident that the globe itself must make a revolution on its axis in that time.

It appears, then, that the rotation of the moon upon its axis being equal to that of its revolution in its orbit, is 27 days, 7 hours, and 44 minutes. The intervals of light and darkness to the inhabitants of the moon, if there were any, would then be altogether different from those provided in the planets; there would be about 13 days of continued light alternately with 13 days of continued darkness; the analogy, then, which prevails among the planets with regard to days and nights, and which forms a main argument in favour of the conclusion that they are inhabited globes like the earth, does not hold good in the case of the moon.

6. While the moon revolves round the earth, its illuminated

Fig. 2.



hemisphere is always presented to the sun; it therefore takes various positions in reference to the earth. The effects of this are exhibited in the annexed fig. 2. Let E S represent the direction

of the sun, and E the earth; when the moon is at N, between the sun and the earth, its illuminated hemisphere being turned toward the sun, its dark hemisphere will be presented toward the earth; it will therefore be invisible. In this position the moon is said to be in CONJUNCTION.

When it moves to the position C, the enlightened hemisphere being still presented to the sun, a small portion of it only is turned to the earth, and it appears as a thin crescent, as represented at *c*.

7. When the moon takes the position of Q, at right angles to the sun, it is said to be in QUADRATURE: one half of the enlightened hemisphere only is then presented to the earth, and the moon appears halved as represented at *q*.

When it arrives at the position G, the greater part of the enlightened portion is turned to the earth, and it is gibbous, appearing as represented at *g*.

8. When the moon comes in OPPOSITION to the sun, as seen at F, the enlightened hemisphere is turned full toward the earth, and the moon will appear full as at *f*, unless it be obscured by the earth's shadow, which rarely happens. In the same manner it is shown that at G′ it is again gibbous; at Q′ it is halved, and at C′ it is a crescent.

If the moon or the planets be supposed to be viewed by an observer placed on the one side or the other of the general plane in which they move, they will appear to move either in the direction of the hands of a clock, or in the contrary direction, according to the side of the general plane from which they are seen. If the observer be supposed to be on the north side of that plane, their motion will be contrary to that of the hands of a clock. If he is placed on the south side of that plane, their motion will be in the direction of the hands of a clock.

In the case represented in fig. 2, and also in the astronomical diagrams in the first volume of the Museum, pp. 5, 11, &c., the observer is supposed to be placed at the south side of the general plane.

9. In order to determine whether or not the globe of the moon is surrounded with any gaseous envelope like the atmosphere of the earth, it is necessary first to consider what appearances such an appendage would present, seen at the moon's distance, and whether any such appearances are discoverable.

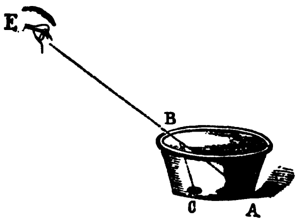
10. According to ordinary and popular notions, it is difficult to separate the idea of an atmosphere from the existence of clouds; yet to produce *clouds something* more is necessary than air. The *presence of water is indispensable*, and if it be assumed that no *water exist, then certainly* the absence of clouds is no proof of the

absence of an atmosphere. Be this as it may, however, it is certain that there are no clouds upon the moon, for if there were, we should immediately discover them, by the variable lights and shadows they would produce. If there be an atmosphere upon the moon, it is therefore one entirely unaccompanied by clouds.

11. One of the effects produced by a distant view of an atmosphere surrounding a globe, one hemisphere of which is illuminated by the sun, is, that the boundary, or line of separation between the hemisphere enlightened by the sun and the dark hemisphere, is not sudden and sharply defined, but is gradual—the light fading away by slow degrees into the darkness. It is to this effect upon the globe of the earth that twilight is owing, and as we shall see hereafter, such a gradual fading away of the sun's light is discoverable on some of the planets, upon which an atmosphere is observed. Now, if such an effect of an atmosphere were produced upon the moon, it would be perceived by the naked eye, and still more distinctly with the telescope. When the moon appears as a crescent, its concave edge is the boundary which separates the enlightened from the dark hemisphere. When it is in the quarters, the diameter of the semicircle is also that boundary. In neither of these cases, however, do we ever discover any gradual fading away of the light into the darkness; on the contrary, the boundary, though serrated and irregular, is nevertheless perfectly well defined and sudden. All these circumstances conspire to prove that there does not exist upon the moon an atmosphere capable of refracting light in any sensible degree.

But it may be contended that an atmosphere may still exist, though too attenuated to produce a sensible twilight. Astronomers, however, have resorted to another test of a much more decisive and delicate kind, the nature of which will be understood by explaining a simple principle of optics. When a ray of light passes through a transparent medium, such as air, water, or glass, it is generally deflected from its rectilinear course, so as to form an angle. A simple and easily-executed experiment will render this intelligible. Let a visible object, such as a coin, be placed at C, in the bottom of a

Fig. 3.



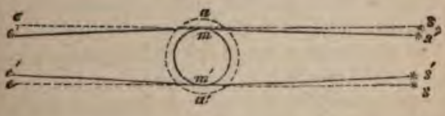
bucket. Let the eye be placed at E (fig. 3), so that the side of the *bucket, when empty*, shall just conceal the coin, and so that the *nearest point to* the coin visible shall be at A, in the direction of *the line* E B A. Let the bucket be now filled with water, and the

coin will become immediately visible; the reason of which is, that the ray of light C B proceeding from the coin is bent at an angle in passing from the water into the air, and reaches the eye by the angular course C B E. Thus it appears that the coin will be visible to the eye, notwithstanding the interposition of the opaque side of the bucket.

Let us see how this principle can be applied to the case of the moon's atmosphere, if such there be.

Let *m m'* (fig. 4) represent the disk of the moon. Let *a a'* represent the atmosphere which surrounds it. Let *s m e* and *s m' e* represent two lines touching the moon at *m* and *m'*, and proceeding towards the earth. Let *s s* be two stars seen in the direction of these lines. If the moon had no atmosphere, these stars would appear to touch the edge of the moon at *m* and *m'*, because the rays of light from them would pass directly toward the earth; but if the moon have an atmosphere, then that atmosphere will possess the property which is common to all transparent media of refracting light, and, in virtue of such pro-

Fig. 4.



perty, stars in such positions as *s' s'*, behind the edge of the moon, would be visible at the earth, for the ray *s' m*, *s' m'*, in passing through the atmosphere, would be bent at an angle in the direction *m e'*, and *m' e'*, so that the stars *s' s'* would be visible at *e' e'*, notwithstanding the interposition of the edges of the moon.

This reasoning leads to the conclusion that as the moon moves over the face of the firmament, stars will be continually visible at its edge which are really behind it if it have an atmosphere, and the extent to which this effect will take place will be in proportion to the density of the atmosphere.

12. The magnitude and motion of the moon and the relative positions of the stars are so accurately known that nothing is more easy, certain, and precise, than the observations which may be made with the view of ascertaining whether any stars are ever seen which are sensibly behind the edge of the moon. Such observations have been made, and no such effect has ever been detected. This species of observation is susceptible of such extreme accuracy, that it is certain that if an atmosphere existed upon the

moon a thousand times less dense than our own, its presence must be detected.

13. The earth's atmosphere supports a column of 30 inches of mercury: an atmosphere 1000 times less dense would support no more than the thirtieth of an inch. It may therefore be considered as proved that the space around the surface of the moon is as exempt from an atmosphere as is the receiver of a good air-pump after that instrument has exhausted it of air to the utmost limit of its power. In fine for all practical purposes it is demonstrated that the moon has no atmosphere.

14. The same physical tests which show the non-existence of an atmosphere of air upon the moon are equally conclusive against an atmosphere of vapour. It might, therefore, be inferred that no liquids can exist on the moon's surface, since they would be subject to evaporation. Sir John Herschel, however, ingeniously suggests that the non-existence of vapour is not conclusive against evaporation. One hemisphere of the moon being exposed continuously for 328 hours to the glare of sunshine of an intensity greater than a tropical noon, because of the absence of an atmosphere and clouds to mitigate it, while the other is for an equal interval exposed to a cold far more rigorous than that which prevails on the summits of the loftiest mountains or in the polar regions, the consequence would be the immediate evaporation of all liquids which might happen to exist on the one hemisphere, and the instantaneous condensation and congelation of the vapour on the other. The vapour would, in short, be no sooner formed on the enlightened hemisphere than it would rush to the vacuum over the dark hemisphere, where it would be instantly condensed and congealed, an effect which Herschel aptly illustrates by the familiar experiment of the CRYOPHOROUS. The consequence, as he observes, of this state of things would be absolute aridity below the vertical sun, constant accretion of hoar frost in the opposite region, and perhaps a narrow zone of running waters at the borders of the enlightened hemisphere. He conjectures that this rapid alternation of evaporation and condensation may to some extent preserve an equilibrium of temperature, and mitigate the severity of both the diurnal and nocturnal conditions of the surface. He admits nevertheless that such a supposition could only be compatible with the tests of the absence of a transparent atmosphere even of vapour within extremely narrow limits; and it remains to be seen whether the general physical condition of the lunar surface as disclosed by the telescope be not more compatible with the supposition of the total absence of all liquid whatever.

It appears to have escaped the attention of those who assume

the possibility of the existence of water in the liquid state on the moon, that, in the absence of an atmosphere, the temperature must necessarily be, not only far below the point of congelation of water, but even that of most other known liquids. Even within the tropics, and under the line with a vertical sun, the height of the snow line does not exceed 16000 feet, and nevertheless at that elevation, and still higher, there prevails an atmosphere capable of supporting a considerable column of mercury. At somewhat greater elevations, but still in an atmosphere of very sensible density, mercury is congealed. Analogy, therefore, justifies the inference that the total, or nearly total, absence of air upon the moon is altogether incompatible with the existence of water, or probably any other body in the liquid state, and necessarily infers a temperature altogether incompatible with the existence of organised beings in any respect analogous to those which inhabit the earth.

But another conclusive evidence of the non-existence of liquids on the moon is found in the form of its surface, which exhibits none of those well understood appearances which result from the long-continued action of water. The mountain formations with which the entire visible surface is covered are, as will presently appear, universally so abrupt, precipitous, and unchangeable, as to be utterly incompatible with the presence of liquids.

15. The general diffusion of the sun's light upon the earth is mainly due to the reflection and refraction of the atmosphere, and to the light reflected by the clouds; and without such means of diffusion the solar light would only illuminate those places into which its rays would directly penetrate. Every place not in full sunshine, or exposed to some illuminated surface, would be involved in the most pitchy darkness. The sky at noon-day would be intensely black, for the beautiful azure of our firmament in the day-time is due to the reflected colour of the air. Thus it appears that the absence of air on the moon must deprive the sun's illuminating and heating agency of nearly all its utility.

16. If the moon were inhabited, observers placed upon it would witness celestial phenomena of a singular description, differing in many respects from those presented to the inhabitants of our globe. The heavens would be perpetually serene and cloudless. The stars and planets would shine with extraordinary splendour during the long night of 328 hours. The inclination of her axis being only 5°, there would be no sensible changes of season. The year would consist of one unbroken monotony of equinox. The inhabitants of one hemisphere would never see the earth: while the inhabitants of *the other* would have it constantly in their *firmament by day and by night,* and always in the same position.

To those who inhabit the central part of the hemisphere presented to us, the earth would appear stationary in the zenith, and would never leave it, never rising nor setting, nor in any degree changing its position in relation to the zenith or horizon. To those who inhabit places intermediate between the central part of that hemisphere and those places which are at the edge of the moon's disk, the earth would appear at a fixed and invariable distance from the zenith, and also at a fixed and invariable azimuth, the distance from the zenith being everywhere equal to the distance of the observer from the middle point of the hemisphere presented to the earth. To an observer at any of the places which are at the edge of the lunar disk, the earth would appear perpetually in a fixed direction on the horizon.

The earth shone upon by the sun would appear as the moon does to us; but with a disk having an apparent diameter greater than that of the moon in the ratio of 79 to 21, and an apparent superficial magnitude about fourteen times greater, and it would consequently have a proportionately illuminating power.

Earth light at the moon would, in fine, be about fourteen times more intense than *moonlight* at the earth. The earth would go through the same phases and complete the series of them in the same period as that which regulates the succession of the lunar phases, but the corresponding phases would be separated by the interval of half a month. When the moon is *full* to the earth, the earth is *new* to the moon, and *vice versâ:* when the moon is a crescent, the earth is gibbous, and *vice versâ*.

17. The features of light and shade would not, as on the moon, be all permanent and invariable. So far as they would arise from the clouds floating in the terrestrial atmosphere they would be variable. Nevertheless, their arrangement would have a certain relation to the equator, owing to the effect of the prevailing atmospheric currents parallel to the line. This cause would produce streaks of light and shade, the general direction of which would be at right angles to the earth's axis, and the appearance of which would be in all respects similar to the BELTS which are observed upon some of the planets, and which are ascribed to a like physical cause.

18. Through the openings of the clouds the permanent geographical features of the surface of the earth would be apparent, and would probably exhibit a variety of tints according to the prevailing characters of the soil, as is observed to be the case with the planet Mars even at an immensely greater distance. The rotation of the earth upon its axis would be distinctly observed and its time ascertained. The continents and seas would disappear in succession at one side and reappear at the other, passing across the disk of the earth as carried round by the diurnal rotation.

19. It has long been an object of inquiry among philosophers whether the light of the moon has any heat, but the most delicate experiments and observations have failed to detect this property in it. A thermometer of extreme sensibility, called a differential thermometer, was the instrument applied to this inquiry.

This instrument consists of two glass bulbs, A and B (fig. 5), connected by a rectangular glass tube. In the horizontal part of the tube a small quantity of coloured liquid (sulphuric acid, for example) is placed. Atmospheric air is contained in the bulbs and tube, separated into two parts by the liquid. The instrument is so adjusted that, when the drop of liquid is at the middle of the horizontal tube, the air in the bulbs has the same pressure; and having equal volumes, the quantities at each side of the liquid are necessarily equal. If the bulbs be affected by different temperatures, the liquid will be pressed from that side at which the

Fig. 5.

temperature is greatest, and the extent of its departure from the zero or middle is indicated by the scale. This thermometer is sometimes varied in its form and arrangement, but the principle remains the same. Its extreme sensitiveness, in virtue of which it indicates changes of temperature too minute to be observed by common thermometers, renders it extremely valuable as an instrument of scientific research. By this instrument, changes of temperature not exceeding the 6000th part of a degree are rendered sensible.

The light of the moon was collected into the focus of a concave mirror of such magnitude as would have been sufficient, if exposed to the sun's light, to evaporate gold or platinum. The bulb of the differential thermometer was placed in its focus, so as to receive upon it the concentrated rays of the moon. Yet no sensible effect was produced upon the thermometer. We must therefore conclude that the light of the moon does not possess the calorific property *in any sensible degree.*

This result will create less surprise when the comparative

intensity of sunlight and moonlight are considered. It may be assumed, without sensible error, that the intensity of the sun's light on the surface of the moon and on the earth is the same; it follows from this, that supposing no light whatever to be absorbed by the moon, but the entire light of the sun to be reflected from its surface undiminished, the intensity of moonlight at the earth would bear to the intensity of sunlight the same proportion as the magnitude of the moon bears to the magnitude of the entire firmament, that is, the proportion very nearly of 1 to 300000; but there is no reflecting surface, however perfect, which does not absorb the light incident upon it in a very considerable degree, and the rugged surface of the moon must be a most imperfect reflector. It may then be considered as demonstrated that the intensity of moonlight is much more than 300000 times more feeble than that of sunlight. We shall not, then, be surprised at the absence of its heating power.

But if the rays of the moon be not warm, the vulgar impression that they are cold is equally erroneous. We have seen that they produce no effect either way on the thermometer.

20. Curiosity will doubtless be awakened in a very lively manner regarding the physical condition of our moon: what part has the Maker of the solar system destined this body to play in the economy of His creation? Is it a globe teeming with life and organisation like the earth? Is that orb, which rolls in silent majesty through the midnight firmament, the abode of life and intelligence? The beauty of her appearance naturally leads the mind to conjectures of this kind. Yet the circumstances which I have unfolded regarding the total absence of air and water appear to exclude the possibility of any such supposition. How, may it be asked, can it be conceived that a globe can have upon it an organised world which is destitute of fluid matter in every form? How can growth, which implies gradual change, increase, and diminution, and all the various effects in which fluidity is an agent, go on there? How can they proceed upon such a solid, arid, unchangeable, crude mass? Let it be remembered what a multitude of purposes in our natural and social economy are subserved by the combination of the water and the atmosphere of our globe. None of these purposes can be fulfilled upon the moon. Perhaps, however, our notions on such questions may be cleared up to some extent by a careful examination of the facts that scientific research has collected respecting the physical condition of the surface of our satellite.

21. If, when the moon is a crescent, we examine with a telescope, even of moderate power, the concave boundary which is that part of the lunar surface where the enlightened hemisphere

ends and the dark hemisphere begins, we shall find that it is not an even and regular curve, which it undoubtedly would be if the surface of the globe of the moon were smooth and regular, or nearly so. If, for example, the lunar surface resembled in its general characteristics that of our globe; granting the total absence of water, and that the entire surface is land, but that land had the general characteristics of the continents of the globe of the earth; then I say, that the inner boundary of the lunar crescent would still be a regular curve, broken or interrupted only at particular points. Where great mountain ranges, like those of the Alps, the Andes, or the Himalaya, might chance to cross it, these lofty peaks would project vastly-elongated shadows along the adjacent plain; for it will be remembered that, being situated at the moment in question at the boundary of the enlightened and darkened hemispheres, the shadows would be those of evening and morning; which are prodigiously longer than the objects themselves. The effects of these would be to cause gaps or irregularities in the general outline of the inner boundary of the crescent; with these rare exceptions, the inner boundary of the crescent produced by a globe like the earth would be an even and regular curve.

Such, however, is not the case with the inner boundary of the lunar crescent, even when viewed by the naked eye, and still less so when magnified by a telescope. It is found, on the contrary, rugged and serrated, and brilliantly illuminated points are seen in the dark parts at some distance from it, while dark shadows of considerable length appear to break into the illuminated surface. The inequalities thus apparent indicate singular characteristics of the surface. The bright points seen within the dark hemisphere are the peaks of lofty mountains tinged with the sun's light. They are in the condition with which all travellers in Alpine countries are familiar; after the sun has set, and darkness has set in over the valleys at the foot of the chain, the sun still continues to illuminate the peaks above. The sketch (*fig. 6*), *of the lunar* crescent, will illustrate these *observations.*

Fig. 6.

22. The visible hemisphere of our satellite has, within the last quarter of a century, been subjected to the most rigorous examination which unwearied industry, aided by the vast improvement which has been effected in the instruments of telescopic observation, rendered possible; and it is no exaggeration to state that we now possess a chart of that hemisphere, which in accuracy of detail far exceeds any similar representation of the earth's surface.

Among the selenographical observers, the Prussian astronomers, MM. Beer and Mädler, stand pre-eminent. Their descriptive work, entitled "Der Monde," contains the most complete collection of observations on the physical condition of our satellite, and the chart, measuring 37 inches in diameter, exhibits the most complete representation of the lunar surface extant. Besides this great work, a selenographic chart was produced by Mr. Russel, from observations made with a seven-foot reflector, a similar delineation by Lohrmann, and, in fine, a very complete model in relief of the visible hemisphere by Madame Witte, a Hanoverian lady.

23. The surface of the visible hemisphere is thickly covered with mountainous masses and ranges of various forms, magnitudes, and heights, in which, however, the prevalence of a circular or crater-like form is conspicuous. The various tints of white and gray which mark the lineaments observed upon the disk arise partly from the different reflecting powers of the matter composing different parts of the lunar surface, and partly from the different angles at which the rays of the solar light are incident upon them. The more intensely white parts are mountains of various magnitude and form, whose height, relatively to the moon's magnitude, greatly exceeds that of the most stupendous terrestrial eminences; and there are many characterised by an abruptness and steepness which sometimes assume the position of a vast vertical wall, altogether without example upon the earth. These are generally disposed in broad masses, lying in close contiguity, and intersected with vast and deep valleys, gullies, and abysses, none of which, however, have any of the characters which betray the agency of water.

24. There are circular areas, varying from 40 to 120 miles in diameter, enclosed by a ring of mountain ridges, mostly continuous, but in some cases intersected at one or more points by vast ravines. The enclosed area is generally a plain on which mountains of less height are often scattered. The surrounding circular ridge also throws out spurs, both externally and internally, but the latter are generally shorter than the former. In some cases, however, internal spurs, which are diametrically opposed, unite

in the middle so as to cut in two the enclosed plain. In some rare cases the enclosed plain is uninterrupted by mountains, and it is almost invariably depressed below the general level of the surrounding land. A few instances are presented of the enclosed plain being convex.

The mountainous circle enclosing these vast areas is seldom a single ridge. It consists more generally of several concentric ridges, one of which, however, always dominates over the rest, and exhibits an unequal summit, broken by stupendous peaks, which here and there shoot up from it to vast heights. Occasionally it is also interrupted by smaller mountains of the circular form.

25. The most remarkable of the class of lunar mountains, called ring mountains, is that called TYCHO. This object is distinguishable without a telescope on the lunar disk when full; but, owing to the multitude of other features which become apparent around it in the phases, it can then be only distinguished by a perfect knowledge of its position, and with a good telescope. The enclosed area, which is very nearly circular, is 47 miles in diameter, and the inside of the enclosing ridge has the steepness of a wall. Its height above the level of the enclosed plain is 16000 feet, and above that of the external regions 12000 feet. There is a central mountain, having the height 4700 feet, besides a few lesser hills within the enclosure.

This region of the moon is represented in the engraving at the head of this tract, copied and reduced from the chart of MM. Beer and Mädler. The volcanic character observed in the mountain formations loses much of its analogy to like formations on the earth's surface when higher magnifying powers enable us to examine the forms of what appear to be craters, and to compare their dimensions with even the most extensive terrestrial craters. Numerous examples may be produced to illustrate this. Tycho, which, viewed under a moderate magnifying power, appears to possess in so eminent a degree the volcanic character, is, as has been stated, a circular chain enclosing an area of 47 miles in diameter. Gassendi, another system of like form, and of still more stupendous dimensions, as seen with high magnifying powers, consists of two enormous circular chains of mountains, the lesser, which lies to the north, measuring 16½ miles in diameter, and the greater, lying to the south, enclosing an area 60 miles in diameter. The area enclosed by the former is therefore 214, and by the latter 2827 square miles. The height of the lesser chain is about 10000 feet, while that of the greater varies from 3500 to 5000 feet. The vast area thus enclosed by the greater chain *includes, at or near its* centre, a principal central mountain, *having eight peaks and* an height of 2000 feet, while scattered

over the surrounding enclosure upwards of a hundred mountains of less considerable elevation have been counted.

It is easy to see how little analogy to a terrestrial volcanic crater is presented by these characters.

26. In the work of Beer and Mädler a table of the heights of above 1000 mountains is given, several of which attain to an elevation of 23000 feet, equal to that of the highest summits of terrestrial mountains, while the diameter of the moon is little more than a fourth of that of the earth.

27. By means of the great reflecting telescope of Lord Rosse, the flat bottom of the crater called Albategnius is distinctly seen to be strewed with blocks, not visible with less powerful instruments; while the exterior of another (Aristillus) is intersected with deep gullies radiating from its centre.

28. In fine, the entire geographical character of the moon, thus ascertained by long-continued and exact telescopic surveys, leads to the conclusion that no analogy exists between it and the earth which would confer any probability on the conjecture that it fulfils the same purposes in the economy of the Universe, and we must infer that whatever be its uses in the solar system, or in the general purposes of creation, it is not a world inhabited by organised races, such as those to which the earth is appropriated.

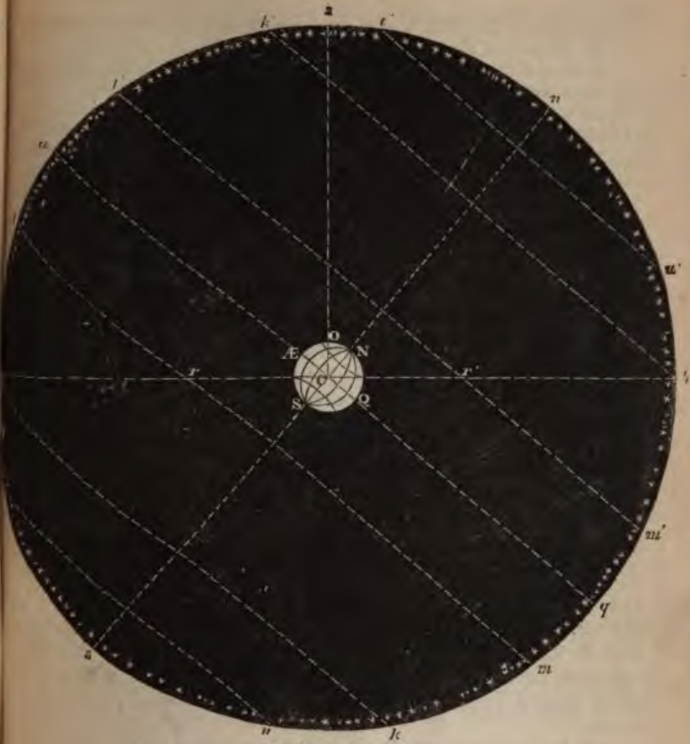


Fig. 2.

COMMON THINGS.

THE EARTH.

1. Difficulty of observing the earth as a whole.—2. It appears at first an indefinite flat surface.—3. This disproved by travelling round it.—4. Proof of the curvature of its surface by observation of distant objects at sea.—5. By the Earth's shadow projected on the Moon.—6. Inequalities of surface, such as mountains and valleys, insignificant.—7. Magnitude of Earth, how ascertained.—8. Length of a degree of latitude.—9-10. Illustrations of the Earth's magnitude.—11. Is the Earth at rest?—12. Apparent motion of the firmament.—13. Origin of the word "Universe."—14. This apparent motion may not be real—may arise *from the rotation of the* Earth.—15. How such a rotation *would produce it.—16. Poles.—17.* Equator.—18. Hemispheres.—19.

Meridians.—20. Which of the two rotations is the more probable?—21. Rotation of the universe impossible.—22. Simplicity of the supposed rotation of the globe.—23. Direct proofs of this motion.—24. Foucault's experiment.—25. Its analogy to the planets.—26. Conclusion as to the globular form of the earth requires modification.—27. All human knowledge tentative and approximative.—28. Rotation not compatible with the exact globular form.—29. Centrifugal force of the Earth's rotation.—30. The globe rotating would assume the form of an oblate spheroid.—31. The degree of ellipticity would vary with the velocity of rotation.—32. Experimental illustration.—33. Ellipticity corresponding to the diurnal rotation.—34. How these circumstances affect the actual state of the Earth.—35. Form of a terrestrial meridian.—36. Dimensions of the terrestrial spheroid.—37. Its departure from an exact globe very small.—38. Its density and mass.—39. Determined by Cavendish and Maskelyne.—40. Its total weight.

1. Locke somewhere observes, with his usual felicity of illustration, that the "mind, like the eye, while it makes us see and perceive all other things, can never turn its view with advantage upon itself." We encounter something similar to this in our researches through the universe; for of all the objects which compose it, one of the most difficult of which to obtain a complete and accurate knowledge is the planet which we inhabit. The cause of this is our proximity to it, and intimate connexion with it. We are confined upon its surface, from which we cannot separate ourselves. We cannot obtain a bird's-eye view of it, nor at any one time behold more than an insignificant portion of its surface. We have the same difficulty in obtaining an acquaintance with it that a microscopic animalcule would have in acquiring a perfect knowledge of the form and dimensions of a terrestrial globe twelve inches in diameter, on the surface of which it creeps.

Still, by a variety of indirect methods supplied by the ingenuity of scientific research, we have been enabled to ascertain its form, dimensions, and physical constitution, with a considerable degree of accuracy.

2. The first impression produced upon the eye of an observer, who has not carried his inquiries further, is, that the surface of the earth is a flat plane, interrupted only by the inequalities of the land. A little careful observation, however, upon the many phenomena which are easily accessible to every observer, will correct this erroneous impression.

3. It is well known that if a voyage were made upon the earth, continually preserving one and the same direction, or doing so as nearly as circumstances will permit, we should at length arrive at the place from which we departed. If the earth were an *indefinite plane*, this could not happen. It is evident, then, that whatever be the exact form of the earth, it is a body which is on

every side limited, and one which must therefore have such a surface that a traveller or navigator can completely surround it in one continuous course.

4. Let us see, however, whether we may not obtain evidence more distinct as to its form. If we stand on the deck of a ship at sea, and out of sight of land, the view being bounded only by sea and sky, and look at the horizon when a ship (A, fig. 1) approaches, we shall at first see its topmast rising out of the water like a pole.

Fig. 1.

As it gradually comes nearer to us (as at B), more of the mast will become visible, and the sails will be seen—cut off, however, horizontally, by the line at which the water and sky unite. Upon the nearer approach of the ship (as at C and D), the hull will at length become visible. Now since this takes place on all sides around us, it will follow that when the ship is at a distance, there must be *something* interposed between the eye and it which intercepts the view of it; but as the surface of the water is generally uniform, and not subject to sudden and occasional inequalities like that of the land, we can only imagine its general form to be convex, and that its convexity is interposed between the eye and the object so as to intercept the view.

Since the same effects are observed from whatever direction the ship may approach, it will follow that the same convexity must prevail on every side.

If, on the contrary, the surface extending from the eye to the ship were a plane, the ship would be rendered invisible only by reason of its distance; whereas it is ascertained that a ship frequently is invisible at a distance at which it must be seen but for the interposition of some other object; this may be tested, and in fact is frequently tested at sea by mounting to the masthead, whence the seaman being enabled to overlook the convexity, sees vessels which are invisible from the deck, although, strictly speaking, he is nearer to those vessels on the deck than at the masthead.

When the mariner, after completing a long voyage, discovers by his observations and reckonings that he is approaching the desired coast, he ascends to the topmast and looks out for the appearance of mountains or other elevated land, and he invariably sees them *from that point long before* they are visible from the deck. He

afterwards sees them from the deck long before the general level of the country will be observed by him. All these are natural and necessary consequences of the convexity of the surface of the ocean. The same effects would be seen in any part of a continent which is sufficiently free from mountains and other inequalities.

5. But we have a still more conclusive and convincing proof of the general form of the earth even than those which have been explained. When the moon passes directly behind the earth, so that the shadow which the earth projects behind it in the direction opposite to the sun shall fall upon the moon, we invariably find that shadow to be, not as is commonly said, circular, but such exactly as one globe would project upon the surface of another globe. Now, as this takes place always, in whatever position the earth may be, and while the earth is revolving rapidly with its diurnal motion upon its axis, it follows that the earth must either be an exact globe or so little different from a globe that its deviation from that figure is undiscoverable in its shadow.

We may, then, consider it demonstrated that the earth may be practically regarded as globular in its form. We shall hereafter see that it slightly departs from the spherical figure, but our present purpose will be best answered by regarding it as a globe.

6. The objection will doubtless occur to many minds that the inequality which exists on the surface of that portion of the globe that is covered by land, especially the loftier ridges of mountains, such as the Andes, the Alps, the Himalaya, and others, are incompatible with the idea of a globular figure. If the term globular figure were used in the strictest geometrical sense, this objection doubtlessly would have great force. But let us see the real extent of this presumed deviation from the globular form. The highest mountain on the surface of the globe does not exceed five miles above the general level of the sea. The entire diameter of the globe, as we shall presently see, is eight thousand miles. The proportion, then, which the highest summit of the loftiest mountains bears to the entire diameter of the globe will be that of five to eight thousand, or one to sixteen hundred. If we take an ordinary terrestrial globe of sixteen inches in diameter, each inch upon the globe will correspond to five hundred miles upon the earth, and the sixteen hundredth part of its diameter, or the hundredth part of an inch, will correspond to five miles. If, then, we take a narrow strip of paper, so thin that it would take one hundred leaves to make an inch in thickness, and paste such a strip on the surface of the globe, the thickness of the strip would represent upon the sixteen-inch globe the height of the loftiest mountain on the earth. We are then to consider that the highest

mountain-ranges on the earth deprive it of its globular figure only in the same degree and to the same extent as a sixteen-inch globe would be deprived of its globular figure by a strip of paper pasted upon it the hundredth part of an inch thick.

It is supposed that the greatest depth of the ocean which covers any portion of the globe does not exceed the greatest height of the mountains upon the land. If this be true, the ocean upon the earth might be represented by a film of liquid laid with a camel's hair pencil upon the surface of a sixteen-inch globe.

It is apparent, therefore, that depths and heights which appear to the common observer to be stupendous, are nothing when considered with reference to the magnitude of the earth; and that, so far as they are concerned, we may practically regard the earth as a true globe.

7. Having ascertained satisfactorily the form of the earth, our next enquiry must be as to its magnitude; and since it is a globe, all that we are required to know is the length of its diameter.

If a line were described surrounding the globe, so as to form a circle upon it, the centre of which should be at the centre of the globe, such a circle is called a *great circle* of the earth. Now if we know the length of the circumference of such a circle, we could easily calculate the length of its diameter, for the proportion of the circumference to the diameter is exactly known. But we could calculate the circumference if we knew the length of one degree upon it, since we know that the circumference consists of three hundred and sixty degrees; we should therefore only have to multiply the length of one degree by three hundred and sixty to obtain the circumference, and should thence calculate the diameter.

8. In our tract upon latitudes and longitudes, it was shown how the latitude of a place can be ascertained. Now, let us suppose two places selected which are upon the same meridian of the earth, and therefore have the same longitude, and which are not very far removed from each other. Let them, moreover, be selected so that the distance between them can be easily and accurately measured. Now let the latitude of these two places be exactly determined, and let us suppose for example that the difference between these two latitudes is found to be one degree and a half; and supposing also that on measuring the distance between them, that distance is found to be one hundred and four miles and thirty-five hundredths. We should thence infer that such must be the length of one degree and a half of the earth's surface, and that consequently *the length of one* degree would be two thirds of this, *or sixty-nine and a half* miles. Having thus found the length of

a degree, we should have to multiply it by three hundred and sixty, by which we should obtain the circumference of the earth. This would give twenty-five thousand and twenty miles, and we should then find by the usual mode of calculation the diameter of the earth, which would prove to be a little under eight thousand miles.

The fact that a degree of the earth's circumference consists in round numbers of just so many thousand feet as there are days in the year, supplies a very convenient aid to the memory.

We have made these calculations chiefly with a view of rendering the principles of the investigation intelligible. The more exact dimensions of the earth will be explained hereafter.

We conclude, then, that the earth is a globe eight thousand miles in diameter.

9. To enounce this stupendous arithmetical result is much easier than to obtain any distinct notion of the actual magnitude which it expresses. Such a globe has a circumference of twenty-five thousand miles. A locomotive engine travelling incessantly night and day, at twenty-five miles an hour, would take about forty-two days to go round it.

10. When the diameter of a globe is known, its surface and volume or cubical bulk can be easily determined. To find the surface we have only to take three hundred and fourteen hundredths of the square of the diameter, and to find the volume, five hundred and twenty-four thousandths of the cube of the diameter. In this way we find that the surface of the earth measures two hundred millions of square miles, and that its cubical bulk is about two hundred and sixty thousand millions of cubic miles.

If the materials which form such a globe were built up in the form of a vertical column, the base of which would have the magnitude of England and Wales, its height would be nearly four and a half millions of miles!

11. Such being the dimensions of the globe we inhabit, we are next to consider what is its condition as to motion. Is it, as it appears, at rest? For several thousand years in the history of the human race, it was not only so considered, but he that would have ventured to call in question its stability and quiescence would have been deemed insane. Certain expressions in the sacred Scriptures being erroneously supposed to affirm its immobility, it was deemed heretical to deny it; and Galileo, who did so, was put to the torture by the ecclesiastical authorities of the day, and compelled to admit its quiescence. This verbal admission was, however, so utterly opposed to his convictions, that, on quitting the presence of the inquisitors, he stamped on the ground, and muttered the words, "It moves for all that."

12. A few hours' attentive contemplation of the firmament at night will enable any common observer to perceive, that although the stars are, relatively to each other, fixed, the hemisphere, *as a whole*, is in motion. Looking at the zenith, that is the point directly above our head, constellation after constellation will appear to pass across it, having risen in an oblique direction from the horizon at one side, and, after passing the zenith, descending on the other side to the horizon, in a direction similarly oblique. Still more careful and longer continued observation, and a comparison, so far as can be made by the eye, of the different directions successively assumed by the same object, creates a suspicion, which every additional observation strengthens, that the celestial vault has a motion of slow and uniform rotation round a certain diameter as an axis, carrying with it all the objects visible upon it, without in the least deranging their relative positions or disturbing their arrangement.

When these loose impressions of the senses are submitted to the more exact means of observation which are at the disposition of astronomers, it is found that all the appearances of the heavens, the rising and the setting of the stars, the sun and the moon, their apparent motion in ascending to, passing, and descending from, their several points of culmination, are those of a sphere revolving with an uniform motion round the diameter which is directed to the pole.

The world we inhabit therefore would, to judge from these phenomena, seem to be fixed in the centre of a hollow sphere of vast magnitude. On the concave surface of this hollow sphere thus surrounding us at an immeasurable distance all the stars appear to be placed. This sphere, carrying the whole creation upon it, appears to revolve round our world. It makes a complete revolution in twenty-four hours.* By this rotation, the diurnal appearances of the rising and setting of all the heavenly bodies are perfectly explained.

13. The ancients who, as has been stated, affirmed the reality of this motion of the celestial sphere, gave to the whole creation around the earth, the name UNIVERSE; from two words, UNUS, *one*, and VERSUM, *turning* or *rotation*: because they assumed that by an imaginary force, called the PRIMUM MOBILE, or *first impulse*, this rotatory motion had been imparted to the firmament, which ever afterwards retained it.

14. It is easy to perceive that the apparent diurnal rotation of the firmament round the earth may arise indifferently from either of two causes: 1st, from such a real rotation of the firmament

* *More exactly* $23^h\ 56^m\ 4{\cdot}09^s$, but for the present the cause of this *difference need not be noticed.*

once in twenty-four hours; 2ndly, from the rotation of the globe of the earth in the same time round that diameter which is in the direction of the axis round which the firmament appears to revolve.

There is absolutely no other supposition possible but one or other of these. The rejection of either necessarily throws us upon the adoption of the other.

But it may be required that we should show how the rotation of the earth upon an axis passing through the poles would cause the apparent diurnal rotation of the firmament.

15. Let us assume that the earth is a globe revolving uniformly on its axis in twenty-four hours. The universe around it is relatively stationary, and the bodies which compose it being at distances which mere vision cannot appreciate, appear as if they were situate on the surface of a vast celestial sphere in the centre of which the earth revolves. This rotation of the earth gives to the sphere the appearance of revolving in the contrary direction, as the progressive motion of a boat on a river gives to the banks an appearance of retrogressive motion; and since the apparent motion of the heavens is from east to west, the real rotation of the earth which produces that appearance must be from west to east.

How this motion of rotation explains the phenomena of the rising and setting of celestial objects is easily understood. An observer placed at any point upon the surface of the earth is carried round the axis in a circle in twenty-four hours, so that every side of the celestial sphere is in succession exposed to his view. As he is carried upon the side opposite to that in which the sun is placed, he sees the starry heavens visible in the absence of the splendour of that luminary. As he is turned gradually towards the side where the sun is placed, its light begins to appear in the firmament, the dawn of morning is manifested, and the globe continuing to turn, he is brought into view of the luminary itself, and all the phenomena of dawn, morning, and sunrise are exhibited. While he is directed towards the side of the firmament in which the sun is placed, the other bodies of inferior lustre are lost in the splendour of that luminary, and all the phenomena of day are exhibited. When by the continued rotation of the globe the observer begins to be turned away from the direction of the sun, that luminary declines, and at length disappears, producing all the phenomena of evening and sunset.

Such, in general, are the effects which would attend the motion of a spectator placed upon the earth's surface, and carried round with it by its motion of rotation. He is the spectator of a gorgeous diorama exhibited on a vast scale, the earth which forms his station

being the revolving stage by which he is carried round, so as to view in succession the spectacle which surrounds him.

These appearances vary with the position assumed by the observer on this revolving stage; or, in other words, upon his situation on the earth, as will presently appear.

16. That diameter upon which it is necessary to suppose the earth to revolve in order to explain the phenomena is that which passes through the terrestrial poles.

17. If the globe of the earth be imagined to be cut by a plane passing through its centre at right angles to its axis, such a plane will meet the surface in a circle, which will divide it into two hemispheres, at the summits of which the poles are situate. This circle is called the TERRESTRIAL EQUATOR.

18. That hemisphere which includes the continent of Europe is called the NORTHERN HEMISPHERE, and the pole which it includes is called the NORTHERN TERRESTRIAL POLE; the other hemisphere being the SOUTHERN HEMISPHERE, and including the SOUTHERN TERRESTRIAL POLE.

19. If the surface of the earth be imagined to be intersected by planes passing through its axis, they will meet the surface in circles which, passing through the poles, will be at right angles to the equator. These circles are called TERRESTRIAL MERIDIANS, and will be seen delineated on any ordinary terrestrial globe.

These observations will be more clearly comprehended by reference to fig. 2, in which N is the north, and S the south pole of the earth, and Æ Q the equator. The firmament surrounding the earth is represented by the circle *n æ s q*. The axis S N of the earth being supposed to be prolonged to the heavens will meet the firmament at *n* and *s*, the celestial north and south poles; and in like manner the plane of the terrestrial equator Æ Q being continued to the heavens, will meet the firmament at *æ q*, the celestial equator.

If an observer be stationed at O, his zenith will be at *z*, and his horizon at *h h′*. As the globe revolves from west to east, the heavens will be successively brought into view on the east, and will disappear continually on the west.

20. Assuming then that all the diurnal changes of appearance presented by the firmament, the risings and settings of the sun, moon, and stars, and their varying appearance in different latitudes, admit of being explained with equal precision and completeness, either by supposing the universe to revolve daily round the earth, or the earth to revolve daily on its axis, the only question which *remains to be* decided is, which of these two *suppositions is the more probable?*

The fixity and absolute repose of the globe of the earth being assumed by the ancients as a physical maxim which did not even admit of being questioned, they perceived the inevitable character of the alternative which the apparent diurnal rotation of the heavens imposed upon them, and accordingly embraced the hypothesis, which now appears so monstrous, and which is implied in the term UNIVERSE, which they have bequeathed to us.

21. But with the knowledge which has been obtained by the labours of modern astronomers respecting the enormous magnitudes of the principal bodies of the physical universe, magnitudes compared with which that of the globe of the earth dwindles to a mere point, and their distances under the expression of which the very power of number itself almost fails, and recourse is had to colossal units in order to enable it to express even the smallest of them, the hypothesis of the immobility of the earth, and the diurnal rotation of the countless orbs of magnitudes so inconceivable filling the immensity of space once every twenty-four hours round this grain of matter composing our globe, becomes so preposterous that it is rejected, not as an improbability, but as an absurdity too gross to be even for a moment seriously entertained or discussed.

22. But if any ground for hesitation in the rejection of this hypothesis existed, all doubt would be removed by the simplicity and intrinsic probability of the only other physical cause which can produce the phenomena. The rotation of the globe of the earth upon an axis passing through its poles, with an uniform motion from west to east once in twenty-four hours, is a supposition against which not a single reason can be adduced based on improbability. Such a motion explains perfectly the apparent diurnal rotation of the celestial sphere. Being uniform and free from irregularities, checks, or jolts, it would not be perceivable by any local derangement of bodies on the surface of the earth, all of which would participate in it. Observers upon the surface of our globe would be no more conscious of it, than are the voyagers shut up in the cabin of a canal boat, or transported above the clouds in the car of a balloon.

23. It has been shown that a body descending from a great height does not fall in the true vertical line, which it would if the earth were at rest, but eastward of it, which it must, if the earth have a motion of rotation from west to east.

24. An ingenious expedient, by which the diurnal rotation of the earth is rendered visible, has been conceived and reduced to *experiment* by M. Leon Foucault. This contrivance is based upon *the principle*, that the direction of the plane of vibration of a *pendulum* is not affected by any motion of translation which may

be given to its point of suspension. Thus, if a pendulum suspended in a room and put into vibration in a plane parallel to one of the walls, be carried round a circular table, the plane of its vibration will continually be parallel to the same wall, and will therefore vary constantly in the angle it forms with the radius of the table which is directed to it.

Now, if a pendulum, suspended anywhere so near the pole of the earth that the circle round the pole may be considered a plane, be put in vibration in a plane passing through the pole, this plane, continuing parallel to its original direction as it is carried round the pole by the earth's rotation, will make a varying angle with the line drawn to the pole from the position it occupies. After being carried through a quarter of a revolution it will make an angle of 90° with the line to the pole, and so on. In fine, the direction of the pole will appear to be carried round the plane of vibration of the pendulum.

The same effects will be produced at greater distances from the pole, but the rate of variation of the angle under the plane of vibration and the plane of the meridian will be different, owing to the effects of the curvature of the meridian.

This phenomenon, therefore, being a direct effect of the rotation of the earth, supplies a proof of the existence of that motion, attainable without reference to objects beyond the limits of the globe.

25. Another evidence of the rotation of the earth upon its axis is derived from the ascertained fact that the planets which hold places in the solar system similar to that of the earth, do revolve on axes, in times not very different from that of the earth's rotation, as has been shown in our tract upon the Planets.

It may, then, be taken as proved that the earth is not fixed and quiescent, but that it has a rotatory motion round the diameter which passes through its poles, completing a revolution in a day.

26. Having explained the proofs by which we have arrived at the knowledge of the globular form of the earth, it may occasion some surprise that we shall now have to reconsider and modify that conclusion. In this there is nevertheless nothing unusual. It is quite in harmony with all the labours of those who devote themselves to the discovery of the laws of nature.

27. It is the condition of man, and probably of all other finite intelligences, to arrive at the possession of knowledge by the slow and laborious process of a sort of system of trial and error. The first conclusions to which, in physical enquiries, observation conducts us, are never better than very rough approximations to the truth. These, being submitted to subsequent comparison with the originals, undergo a first series of corrections, the more

prominent and conspicuous departures from conformity being removed. A second approximation, but still only an approximation, is thus obtained; and another and still more severe comparison with the phenomena under investigation is made, and another order of corrections is effected, and a closer approximation obtained. Nor does this progressive approach to perfect exactitude appeár to have any limit. The best results of our intellectual labours are still only close resemblances to truth, the absolute perfection of which is probably reserved for a higher intellectual state.

These observations will be illustrated by the process of investigation and discovery in every department of physical science, but in none so frequently and so forcibly as in that which now occupies us.

The first conclusions at which we have arrived respecting the form of the earth is, that it is a globe; and with respect to its motion is, that it is in uniform rotation round one of its diameters, making one complete revolution daily.

28. The first question then which presents itself is, whether this form and rotation are compatible? It is not difficult to show, by the most simple principles of physics, that they are not; that with such a form such a rotation could not be maintained, and that with such a rotation such a form could not permanently continue.

The conclusion that the earth revolves on its axis with a motion corresponding to the apparent rotation of the firmament, is one which admits of no modification, and must from its nature be either absolutely admitted or absolutely rejected. The globular form imputed to the earth, however, has been inferred from observations of a general nature, unattended by any conditions of exact measurement, and which would be equally compatible with innumerable forms, departing to a very considerable and measurable extent from that of an exact geometrical sphere or globe.

29. It is a fact familiar to every one that when a body is whirled round in a circle it has a tendency to fly from the centre. This is called CENTRIFUGAL FORCE. If a stone be whirled round in a sling, this tendency is sensibly felt.

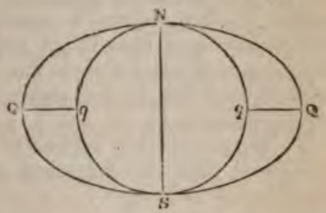
By reason of the rotation of the earth on its axis all the matter composing it, solid and fluid, being carried round the axis in circles of greater or less radius, has this tendency to fly from the axis round which it is thus whirled; and this tendency is stronger for those parts which are more distant than for those which are nearer to the common axis.

30. If the globe thus revolving were composed altogether of matter capable of yielding to the action of such forces, it would

obviously assume a form departing from that of an exact sphere. The parts near the equator would extend themselves to a greater distance from the axis, those more remote from the equator to a less distance, and so on, until, at the pole, the matter would not be at all affected by the rotation. This would be the case if the globe were formed of matter in a liquid or even in a semi-liquid or soft state, or if its materials were elastic.

The form it would take would be one resembling an orange or a turnip. Thus, if N S, fig. 3, be its axis, the equatorial diameter, *q q*, will be stretched out to the increased length, Q Q, while the parts between *q q* and the poles will be less and less extended the nearer they are to the poles, The globe would therefore be changed from the form N *q* S *q*. of a true sphere, to the form N Q S Q, of a flattened globe, called in geometry an OBLATE SPHEROID.

Fig. 3.



31. The elliptic form would depart more and more from a true circle as the motion of rotation is more rapid, so that between the time of rotation and the degree of ellipticity there is a fixed relation, such that when the time of rotation is given, the oval form, or what is the same, the proportion of the equatorial to the polar diameter, can be computed.

32. It is certain, then, that if the earth were composed of fluid, soft or elastic matter, it could not continue to retain the form of a globe, but would become a spheroid, having that degree of ellipticity which would correspond to a motion of rotation, at the rate of one revolution per day, and it is shown by calculation that this ellipticity would be such that the equatorial diameter would be greater than the polar diameter by one three-hundredth part.

33. But the earth, in its present state, is not composed of such yielding materials, and it becomes a question, what, in that case, must be the effect of the diurnal rotation on the distribution of land and water, if the earth were an exact globe.

34. The solid parts of the earth would resist by their cohesion the tendency of the rotation, to cause them to be accumulated and heaped up around the equator; but this would not be the case with the waters composing the seas and oceans. These, by reason of their freedom and mobility would yield to the centrifugal force, and would heap themselves up around the equator, flowing in that direction from *the polar regions* of either hemisphere, so that the *necessary consequences of the* earth having a form exactly

globular, and a diurnal rotation, would be that the surface would consist of two vast polar continents separated by an extensive equatorial ocean.

Such not being the distribution of land and water on the earth, it follows that its form cannot be that of an exact globe.

35. It remains, then, to find means to ascertain by direct measurement and observation, what is the actual form of the earth.

If a terrestrial meridian were an exact circle, as it would necessarily be if the earth were an exact globe, every part of it would have the same curvature. But if it were an ellipse, of which the polar diameter is the lesser axis, it would have a varying curvature, the convexity being greatest at the equator, and least at the poles. If, then, it can be ascertained by observation, that the curvature of a meridian is not uniform, but that on the contrary it increases in going towards the Line, and diminishes in going towards the Poles, we shall obtain a proof that its form is that of an oblate spheroid.

To comprehend the method of ascertaining this, it must be considered that the curvature of circles diminishes as their diameters are augmented.

If, therefore, a degree of the meridian be observed, and measured, at different latitudes, and it is found that its length is not uniformly the same as it would be if the meridian were a circle, but that it is less in approaching the equator, and greater in approaching the pole, it will follow that the convexity or curvature increases towards the equator, and diminishes towards the poles; and that consequently the meridian has the form, not of a circle, but of an ellipse, the lesser axis of which is the polar diameter.

Such observations have accordingly been made, and the lengths of a degree in various latitudes, from the Line to 66° N. and to 35° S., have been measured, and found to vary from 363000 feet on the Line to 367000 feet at lat. 66°.

From a comparison of such measurements, it has been ascertained that the equatorial diameter of the spheroid exceeds the polar by $\frac{1}{300}$th of its length.

Now this is precisely the form, precisely the degree of ellipticity, which a globe, composed of fluid or soft materials, would assume if it had a rotation on its axis once in twenty-four hours.

Thus it appears, that the form of the earth, ascertained by observation, supplies another proof of its diurnal rotation.

36. It is not enough to know the proportions of the earth. It is required to determine the actual dimensions of the spheroid. The following are the lengths of the polar and equatorial diameters,

according to the computations of the most eminent and recent authorities :—

	BESSEL.	AIRY.
	Miles.	Miles.
Polar diameter	7899·114	7899·170
Equatorial diameter	7925·604	7925·648
Absolute difference	26·471	26·478
Excess of the equatorial expressed in a fraction of its entire length . . .	$\frac{1}{299 \cdot 407}$	$\frac{1}{299 \cdot 330}$

The close coincidence of these results supplies a striking example of the precision to which such calculations have been brought.

37. The departure of the terrestrial spheroid from the form of an exact globe is so inconsiderable that, if an exact model of it turned in ivory were placed before us, we could not, either by sight or touch, distinguish it from a perfect billiard ball. A figure of a meridian actually drawn on paper could only be distinguished from a circle by the most precise measurement.

38. The magnitude of the earth being known with great precision, the determination of its mass and that of its mean density become one and the same problem, since the comparison of its mass with its magnitude will give its mean density, and the comparison of its mean density with its magnitude will give its mass.

The methods of ascertaining the mass or actual quantity of matter contained in the earth are all based upon a comparison of the gravitating force or attraction which the earth exerts upon an object with the attraction which some other body, whose mass is exactly known, exerts on the same object. It is assumed, as a postulate or axiom in physics, that two masses of matter which at equal distances exert equal attractions on the same body, must be equal. But as it is not always possible to bring the attracting and attracted bodies to equal distances, their attractions at unequal distances may be observed, and the attractions which they would exert at equal distances may be thence inferred by the general law of gravitation, by which the attraction exerted by the same body increases as the square of the distance from it is diminished.

39. To solve this celebrated problem, it is necessary to bring the whole mass of the globe into direct comparison with some object whose mass is exactly known. This was accomplished first by Dr. Maskelyne, and afterwards by Cavendish. The former compared the attraction of the earth with that of a mountain in Perthshire, called *Schehallion;* the latter compared it with the attraction of a large ball of metal. Both obtained nearly the

same result, showing that the earth is a mass of matter about heavier than an equal volume of water, or, what is the same, tl the mean density of the earth is 5⅔, or, more exactly, 5·67 tin the density of water.

Among the substances which have nearly the same density the earth may be mentioned, arsenic, chromium, chloride of silv oxides of copper and zinc, and peroxide of iron.

40. The average weight of each cubic foot of the earth bei 5·67 times the weight of a cubic foot of water, is 354·375 lbs., 0·1587 of a ton. It follows, therefore, that the total weight the earth is more than 6000,000000 billions of tons.

TERRESTRIAL HEAT.

CHAPTER I.

1. Heat an important agent.—2. Its local variations.—3. Diurnal period.—4. Annual period.—5. Mean diurnal temperature.—6. Mean monthly temperature.—7. Mean annual temperature.—8. Temperature of a place.—9. Isothermal lines.—10. Isothermal zones.—11. Thermal equator.—12. Second isothermal zone.—13. Third.—14. Fourth.—15. Fifth and Sixth.—16. Polar regions.—17. Climate varies on the same isothermal line.—18. Constant, variable, and extreme climates.—19. Classification of climates.—20. Extreme temperature in torrid and frigid zones.—21. Elevation affects temperature.—22. Snow line.—23. Thermal conditions below the surface.—24. Stratum of invariable temperature.—25. Varies with the latitude.—26. Its form.—27. Conditions above it.—28. Conditions below it.—29. Temperature of springs.—30. Temperature of greatest density of water.—31. Thermal condition of seas and

lakes.—32. Thermal condition of a frozen sea.—33. Process of thawing.—34. Depth of stratum of constant temperature. — 35. Superficial agitation extends only to a small depth.—36. Great utility of the state of maximum density.—37. Variations of temperature of the air.—38. Interchange of Equatorial and Polar waters—39. Polar ice.—40. Ice-fields.—41. Icebergs.—42. Their forms and magnitude.—43. Sunken icebergs.—44. Curious effects of their superficial fusion.—45. Depth of Polar Seas.—46. Cold of Polar regions.

1. Of all physical agents, heat is the most intimately connected with the terrestrial economy, the most important to the well-being of the organised tribes which inhabit the earth, and that upon the play of which the most remarkable revolutions which our planet has undergone have been more or less dependent. Since, in some future numbers of this series, we propose to explain these revolutions, and the traces they have left upon the crust of the globe, it will be useful to supply at present some preliminary information as to the laws which regulate the distribution of heat, and the periodical vicissitudes of temperature, on and below the surface of the earth, and in the superior strata of the atmosphere.

2. The superficial temperature of the earth varies with the latitude, gradually decreasing in proceeding from the equator towards the poles.

It also varies with the elevation of the point of observation, decreasing in proceeding to heights above the level of the sea, and varying according to certain conditions below that level, but in all cases increasing gradually for all depths below a certain stratum, at which the temperature is invariable.

At a given latitude and a given elevation the temperature varies with the character of the surface, according as the place of observation is on sea or land; and if on land, according to the nature, productions, or condition of the soil, and the accidents of the surface, such as its inclination or aspect.

3. At a given place the temperature undergoes two principal periodic variations, *diurnal* and *annual.*

The temperature falling to a minimum at a certain moment near sunrise, augments until it attains a maximum, at a certain moment after the sun has passed the meridian. The temperature then gradually falls until it returns to the minimum in the morning.

This diurnal thermometric period varies with the latitude, the elevation of the place, the character of the surface, and with a great variety of local conditions, which not only affect the hours of the maximum, minimum, and mean temperatures, but also the *difference* between the maximum and minimum, or the extent of *the variation.*

4. The annual thermometric period also varies with the latitude, and with all the other conditions that affect the thermal phenomena.

In order to be enabled to evolve the general thermal laws from phenomena so complicated and shifting, it is above all things necessary to define and ascertain those mean conditions or states, round which the thermometric oscillations take place.

5. The mean diurnal temperature is a temperature so taken between the extremes, that all those temperatures which are superior to it shall exceed it by exactly as much as those which are inferior to it shall fall short of it.

This mean temperature may always be obtained by taking the sum of the temperatures at sunrise, at 2 P.M., and at sunset, and dividing the result by 3, or more simply still, by adding together the maximum and minimum temperatures, and taking half their sum. Whichever of these methods be adopted, the same result very nearly will be obtained.

6. The mean temperature of the month is found by dividing the sum of the mean diurnal temperatures by the number of days.

7. The mean temperature of the year may be found by dividing the sum of the mean monthly temperatures by 12.

It is found that in each climate there is a certain month of which the mean temperature is identical with the mean temperature of the year, or very nearly so. This circumstance, when the month is known, supplies an easy method of observing the mean temperature of the year.

In our climate this month is October.

8. The mean annual temperature being observed in a given place for a series of years, the comparison of these means, one with another, will show whether the mean annual temperature is subject to variation, and if so, whether the variation is periodic or progressive. All observations hitherto made and recorded tend to support the conclusion, that the variations of the mean annual temperature are, like all other cosmical phenomena, periodic, and that the oscillations are made within definite limits and definite intervals.

But even though the period of these variations be not known, a near approximation to the mean temperature of the place may be obtained by adding together any attainable number of mean annual temperatures, and dividing their sum by their number. The probable accuracy of the result will be greater, the less the difference between the temperatures computed.

Thus it was found by a comparison of thirty mean annual temperatures at Paris, that the mean was 51°·44, and that the difference *between the greatest* and least of the mean annual *temperatures was only 5°·4.* It may therefore be assumed that

51°·44 does not differ by so much as two-tenths of a degree from the true mean temperature of that place.

Observation, however, has been hitherto so limited, both as to extent and duration, that this thermal character has been determined for a very limited number of places. Indications, nevertheless, have been obtained sufficiently clear and satisfactory to enable Humboldt to arrive at some general conclusions, which we shall now briefly state.

9. In proceeding successively along the same meridian from the equator towards the pole, the mean temperature decreases generally, but not regularly nor uniformly. At some points it even happens that the mean temperature augments, instead of decreasing. These irregularities are caused partly by the varying character of the surface, over which the meridian passes, and partly by the atmospheric effects produced by adjacent regions, and a multitude of other causes, local and accidental. As these causes of irregularity in the rate of decrease of the mean temperature, proceeding from the equator to the poles, are different upon different meridians, it is evident that the points of the meridians which surround the globe, at which the mean temperatures are equal, do not lie upon a parallel of latitude, as they would if the causes which affect the distribution of heat were free from all such irregularities and accidental influences.

If, then, a series of points be taken upon all the meridians surrounding the globe, having the same mean temperature, the line upon which such points are placed is called an *isothermal line*.

Each isothermal line is therefore characterised by the uniform mean temperature which prevails upon every part of it.

10. *Isothermal zones.*—The space included between two isothermal lines of given temperatures is called an *isothermal zone*.

The northern hemisphere has been distributed in relation to its thermal condition into six zones, limited by the six isothermal lines, characterised by the mean temperatures, 86°, 74°, 68°, 59°, 50°, 41°, and 32°.

The first zone is a space surrounding the globe, included between the equator and the isothermal line, whose temperature is 74°.

The mean temperature of the terrestrial equator is subject to very little variation, and it may therefore be considered as very nearly an isothermal line. Its mean temperature varies between the narrow limits of $81\frac{1}{2}°$ and $82\frac{1}{2}°$.

11. If, upon each meridian, the point of greatest mean temperature be taken, the series of such points will follow a certain course round the globe, which has been designated as the *thermal equator*. This line departs from the terrestrial equator, to the extent of ten or twelve degrees on the north, and about eight degrees on the

south side, following a sinuous and irregular course, intersecting the terrestrial equator at about 100° and 160° east longitude.—It attains its greatest distances north at Jamaica, and at a point in Central Africa, having a latitude of 15°, and east longitude 10° or 12°. The greatest mean temperature of the thermal equator is 86°.

The isothermal line having the temperature of 74° is not very sinuous in its course, and does not much depart from the tropics.

12. The second zone, which is included between the isothermal parallels characterised by the mean temperatures of 74° and 68° is much more sinuous, and includes very various latitudes. At the points where it intersects the meridians of Europe, it is convex towards the north, and attains its greatest latitude in Algeria.

13. The third zone, included between the isothermal parallels which have the mean temperatures of 68° and 59°, passes over the coasts of France upon the Mediterranean, about the latitude 43°, and from thence bends southwards, both east and west, on the east towards Nangasaki and the coasts of Japan, and on the west to Natchez on the Mississippi.

14. The fourth zone is included between the parallels of mean temperatures 59° and 50°. It is convex to the north in Europe, including the chief part of France, and thence falls to the south on both sides, including Pekin on the east, and Philadelphia, New York, and Cincinnati on the west. It is evident from this arrangement of the fourth thermal zone, that the climate of Europe is warmer than that of those parts of the eastern and western continents which have the same latitude.

15. The fifth and sixth zones, included between the mean temperatures of 50° and 32°, are more sinuous, and include latitudes more various even than the preceding. The thermometric observations, however, which have been hitherto made in these regions, are too limited to supply ground for any general inferences respecting it.

16. The circle whose area is comprised within the isothermal parallel whose mean temperature is 32°, is still less known. Nevertheless, the results of the observations made by arctic voyagers within the last twenty years, afford ground for inferring that the mean temperature of the pole itself must be somewhere from 13° to 35° below the zero of Fahrenheit, or 45° to 67° below the temperature of melting ice.

17. When it is considered how different are the vegetable productions of places situate upon the same isothermal line, it will be evident that other thermal conditions besides the mean temperature must be ascertained before the climate of a place can be known. Thus London, New York, and Pekin are nearly on

the same isothermal line, yet their climates and vegetable productions are extremely different.

18. One of the circumstances which produce the most marked difference in the climates of places having the same mean temperature is the difference between the extreme temperatures. In this respect climates are classed as *constant*, *variable*, and *extreme*.

Constant climates are those in which the maximum and minimum monthly temperatures differ but little; variable climates are those in which the difference between these extremes is more considerable, and extreme climates are those in which this difference is very great.

Constant climates are sometimes called insular, because the effect of the ocean in equalising the temperature of the air is such as to give this character to the climates of islands.

19. *Examples of the classification of climates.*—The following examples will illustrate this classification of climates:—

Places.	Mean Temp.	Highest Mean Monthly Temp.	Lowest Mean Monthly Temp.	Difference.
Funchal	69°	75°·56	62°·96	12°·60
London	50·36	66·92	41·72	25·20
Paris	51·08	65·30	36·14	29·16
St. Malo	54·14	64·40	37·76	26·64
New York	53·78	80·78	25·34	55·44
Pekin	53·86	84·38	24·62	59·76

Funchal offers the example of a constant or insular climate; London, Paris, and St. Malo, of a variable; and New York and Pekin of an extreme climate.

20. The highest temperature of the air which has been observed within the torrid zone is 130°, which was observed by MM. Lyon and Ritchie, in the Oasis of Mourzouk. This, however, is an extreme and exceptional case, the temperature even in this zone, rarely exceeding 120°.

The lowest temperatures observed by arctic voyagers in the polar regions range from 40° to 60° below zero of Fahrenheit, which is from 70° to 90° below the temperature of melting ice. Thus it appears that the air at the surface of the earth ranges between — 60° and + 120°, the extremes differing by 180°.

21. Innumerable phenomena show that the temperature of the air falls as the elevation increases. The presence of eternal snow

on the elevated parts of mountain ranges, in every part of the globe, not excepting even the torrid zone, is a striking evidence of this.

It appears, from observations made upon the declivities of the vast mountain ranges which traverse the equatorial regions, that the decrease of temperature is neither uniform nor regular.

The observations made in temperate climates give results equally irregular. Gay-Lussac found ascending in a balloon, that the thermometric column fell one degree for an elevation of about 320 feet. On the Alps the height which produces a fall of one degree is from 260 to 280 feet, and on the Pyrenees from 220 to 430 feet. It may be assumed, that in the tropical regions, an elevation of 300 feet, and in our latitudes from 300 to 330 feet, corresponds to a fall of one degree of temperature on an average, subject, however, to considerable local variation.

22. It might appear that in those elevations at which the temperature falls to 32°, water cannot exist in the liquid state, and we might expect that above this limit we should find the surface invested with perpetual snow. Observation nevertheless shows such an inference to be erroneous. Humboldt in the equatorial regions, and M. Leopold de Buch in Norway and Lapland, have shown that the SNOW-LINE does not correspond with a mean temperature of 32° for the superficial atmosphere, but that on the contrary, within the tropics, it is marked by a mean temperature of about 35°, while in the northern regions, in latitudes of from 60° to 70°, the mean temperature is $26\frac{1}{2}$°.

It appears that the snow-line is determined not so much by the mean annual temperature of the air as by the temperature of the hottest month. The higher this temperature is, the more elevated will be the limit of perpetual snow. But the temperature of the hottest month depends on a great variety of local conditions, such as the cloudy state of the atmosphere, the nature of the soil, the inclination and aspect of the surface, the prevailing winds, &c.

23. At a given place the surface of the ground undergoes a periodical variation of temperature, attaining a certain maximum in summer and a minimum in winter, and gradually, but not regularly or uniformly, augmenting from the minimum to the maximum, and decreasing from the maximum to the minimum.

The question then arises as to whether this periodic variation of temperature is propagated downwards through the crust of the earth, and if so, whether in its descent it undergoes any and what modifications?

To explain the phenomena which have been ascertained by observation, let us express the mean temperature by M, and let the *maximum and minimum* temperatures be T and *t*.

If we penetrate to depths more or less considerable, we shall find that the mean temperature M of the strata will be very nearly the same as at the surface. The extreme temperatures T and *t*, will, however, undergo a considerable change, T decreasing, and *t* increasing. Thus the extremes gradually approach each other as the depth increases, the mean M remaining nearly unaltered.

24. A certain depth will therefore be attained at length, when the maximum temperature T, by its continual decrease, and the minimum temperature *t*, by its continual increase, will become respectively equal to the mean temperature M. At this depth, therefore, the periodical variations at the surface disappear; and the mean temperature M is maintained permanently without the least change.

This mean temperature, however, though nearly, is not precisely equal to the mean temperature at the surface. In descending, M undergoes a slight increase, and at the depth where T and *t* become equal to M, and the variation disappears, the mean temperature is a little higher than the mean temperature of the surface.

25. The depth at which the superficial vicissitudes of temperature disappear varies with the latitude, with the nature of the surface, and other circumstances. In our climates it varies from 80 to 100 feet. It diminishes in proceeding towards the equator, and increases towards the pole. The excess of the permanent temperature at this depth above the mean temperature at the surface, increases with the latitude.

The same thermometer which has been kept for sixty years in the vaults of the Observatory at Paris, at the depth of eighty-eight feet below the surface, has shown, during that interval, the temperature of 11°·82 cent., which is equal to 53¼° Fahr., without varying more than half a degree of Fahr., and even this variation, small as it is, has been explained by the effects of currents of air produced by the quarrying operations in the neighbourhood of the Observatory.

26. We must therefore infer, that within the surface of the earth there exists a stratum of which the temperature is invariable, and so placed that all strata superior to it are more or less affected by the thermal vicissitudes of the surface, more so the nearer they are to the surface, and that this stratum of invariable temperature has an irregular form, approaching nearer to the surface at some places, and receding further from it at others, the nature and character of the surface, mountains, valleys, and plains, seas, lakes, and rivers, the greater or less distance from the equator or poles, and a thousand other circumstances, imparting to it variations of form, which it will require observations and experiments

much more long-continued and extensive than have hitherto been made, to render manifest.

27. The thermometric observations on the periodical changes which take place above the stratum of invariable temperature are not so numerous as could be desired; nevertheless, the following general conditions have been ascertained, especially in the middle latitudes of the northern hemisphere:—

1. The diurnal variations of temperature are not sensible to a greater depth than $3\frac{1}{2}$ feet.

2. The difference between the extreme temperatures of the strata decreases in geometrical progression for depths measured in arithmetical progression, or nearly so.

Thus, at the depth of twenty-five feet the difference between the extreme temperatures T and t, is reduced to two degrees; at fifty feet it is diminished to the fifth of a degree, and at sixty or eighty feet to the fiftieth of a degree.

3. Since the effects of the superficial variation must require a certain time to penetrate the strata, it is evident that the epoch at which each stratum attains its maximum and minimum temperatures will be different from those at which the other strata and the surface attain them. The lower the strata the greater will be the difference between the times of attaining those limits as compared with the surface.

28. The same uniformity of temperature which prevails in the invariable stratum is also observed at all greater depths; but the temperature increases with the depth. Thus, each successive stratum, in descending, has a characteristic temperature, which never changes. The rate at which this temperature augments with the depth below the invariable stratum is extremely different in different localities. In some there is an increase of one degree for every thirty feet, while in others the same increase corresponds to a depth of 100 feet. It may be assumed, in general, that an increase of one degree of temperature will take place for every fifty or sixty feet of depth.

29. The permanency of the temperatures of the inferior strata is rendered manifest by the uniformity of the temperature of springs, of which the water rises from any considerable depths. At all seasons of the year the water of such springs maintains the same uniform temperature.

It may be assumed that the temperature of the water proceeding from such springs is that of the strata from which they rise. In these latitudes it is found in general to be a little above the mean temperature of the air for ordinary springs, that is from those which probably *rise from* strata not below the invariable *stratum. In higher latitudes* the excess of temperature is

greater, a fact which is in accordance with what has been already explained.

It has not been certainly ascertained whether the hot springs, some of which rise to a temperature little less than that of boiling water, derive their heat from the great depth of the strata from which they rise, or from local conditions affecting the strata. The uniformity of the temperature of many of them appears to favour the former hypothesis; but it must not be forgotten that other geological conditions besides mere depth may operate with the same permanency and regularity.

30. It is well known that bodies in general expand when they are heated, and contract when they are cooled. Water, when its temperature falls below 40°, presents a most remarkable exception to this general law. It continues in accordance with the law to contract, though in a continually diminished degree, from 40° to 38°·8, and when it arrives at the latter temperature the contraction ceases altogether. When its temperature falls below 38°·8, instead of contracting, it *expands*, and it continues to expand until it is frozen, which takes place at 32°.

It follows from this that the density of water, or its weight bulk for bulk compared with itself at different temperatures is greatest when it has the temperature of 38°·8, which is therefore called the temperature of greatest density.*

31. This anomalous quality of water when its temperature falls below 38°·8 Fahr. and its consequent maximum density at that temperature, is attended with most remarkable and important consequences in the phenomena of the waters of the globe, and in the economy of the tribes of organised creatures which inhabit them. It is easy to show that, but for this provision, exceptional as it seems, disturbances would take place, and changes ensue, which would be attended with effects of the most injurious description in the economy of nature.

If a large collection of water, such as an ocean, a sea, or a lake, be exposed to continued cold, so that its superficial stratum shall have its temperature constantly reduced, the following effects will be manifested.

The superficial stratum falling in temperature, will become heavier, volume for volume, than the strata below it, and will therefore sink, the inferior strata rising and taking its place. These in their turn being cooled will sink, and in this manner a continual system of downward and upward currents will be maintained, by means of which the temperature of the entire mass of liquid will be continually equalised and rendered uniform from

* See Tract on Water (5).

the surface to the bottom. This will continue so long as the superficial stratum is rendered heavier, volume for volume, than those below it, by being lowered in temperature. But the superficial stratum, and all the inferior strata, will at length be reduced to the uniform temperature of 38°·8. After this the system of currents upwards and downwards will cease. The several strata will assume a state of repose. When the superficial stratum is reduced to a temperature lower than 38°·8 (which is that of the maximum density of water), it will become lighter, volume for volume, instead of being heavier than the inferior strata. It will therefore float upon them. The stratum immediately below it, and in contact with it, will be reduced in temperature, but in a less degree; and in like manner a succession of strata, one below the other, to a certain depth, will be lowered in temperature by the cold of those above them, but each stratum being lighter than those below, will remain at rest, and no interchange by currents will take place between stratum and stratum. If water were a good conductor of heat, the cooling effect of the surface would extend downwards to a considerable depth. But water being, on the contrary, an extremely imperfect conductor, the effect of the superficial temperature will extend only to a very limited depth; and at and below that limit, the uniform temperature of 38°·8, that of the greatest density, will be maintained.

This state of repose will continue until the superficial stratum falls to 32° *, after which it will be congealed. When its surface is solidified, if it be still exposed to a cold lower than 32°, the temperature of the surface of the ice will continue to fall, and this reduced temperature will be propagated downward, diminishing, however, in degree, so as to reduce the temperature of the stratum on which the ice rests to 32°, and therefore to continue the process of congelation, and to thicken the ice.

If ice were a good conductor of heat, this downward process of congelation would be continued indefinitely, and it would not be impossible that the entire mass of water from the surface to the bottom, whatever be the depth, might be solidified. Ice, however, is nearly as bad a conductor of heat as water, so that the superficial temperature can be propagated only to a very inconsiderable depth; and it is found accordingly, that the crust of ice formed even on the surface of the polar seas, does not exceed the average thickness of twenty feet.

32. The thermal condition, therefore, of a frozen sea, is a state of molecular repose, as absolute as if the whole mass of liquid were solid. The temperature at the surface of the ice being below the

* *For sea water* the freezing point is 28½°.

freezing point, increases in descending until it rises to the freezing point, at the stratum where the ice ceases, and the liquid water commences. Below this the temperature still augments until it reaches 38°·8, the temperature of maximum density of water, and this temperature is continued uniform to the bottom.

33. Let us now consider what effects will be produced, if the superficial strata be exposed to an increase of temperature. After the fusion of the ice, the temperature of the surface will gradually rise from 32° to 38°·8, the temperature of greatest density. When the superficial stratum rises above 32°, it will become heavier than the stratum under it, and an interchange by currents, and a consequent equalisation of temperature, will take place, and this will continue until the superficial stratum attain the temperature of 38°·8, when the temperature of the whole mass of water from the surface to the bottom will become uniform.

After this a further elevation of the temperature of the superficial stratum will render it lighter than those below it, and no currents will be produced, the liquid remaining at rest; and this state of repose will continue so long as the temperature continues to rise.

Every fall of the superficial temperature, so long as it continues above 38°·8, will be attended with an interchange of currents between the superficial and those inferior strata whose temperature is above 38°·8, and a consequent equalisation of temperature.

34. It appears, therefore, to result as a necessary consequence from what has been explained, and this inference is fully confirmed by experiment and observations, that there exists in oceans, seas, and other large and deep collections of water, a certain stratum, which retains permanently, and without the slightest variation, the temperature of 38°·8, which characterises the state of greatest density, and that all the inferior strata equally share this temperature. At the lower latitudes, the superior strata have a higher, at the higher latitudes a lower temperature, and at a certain mean latitude the stratum of invariable temperature coincides with the surface.

In accordance with this, it has been found by observation that in the torrid zone, where the superficial temperature of the sea is about 83°, the temperature decreases with the depth until we attain the stratum of invariable temperature, the depth of which, upon the Line, is estimated at about 7000 feet. The depth of this stratum gradually diminishes as the latitude increases, and the *limit* at which it coincides with the surface is somewhere between *55° and 60°*. Above this the temperature of the sea increases as *the depth* of the stratum increases, until we sink to the stratum

of invariable temperature, the depth of which at the highest latitudes at which observations have been made, is estimated at about 4500 feet.

35. It might be imagined that the temperature of the surface would be propagated downwards, and that a thermal equalisation might therefore be produced by the intermixture of the superior with the inferior strata, arising from the agitation of the surface of the waters by atmospheric commotions. It is found, however, that these effects, even in the case of the most violent storms and hurricanes, extend to no great depth, and that while the surface of the ocean is furrowed by waves of the greatest height and extent, the inferior strata are in the most absolute repose.

36. If water followed the general law, in virtue of which all bodies become more dense as their temperature is lowered, a continued frost might congeal the ocean from its surface to the bottom, and certainly would do so in the polar regions; for in that case the system of vertical currents, passing upwards and downwards, and producing an equalisation of temperature, which has been shown to prevail above 38°·8, would equally prevail below that point, and consequently the same equalisation of temperature would be continued, until the entire mass of water, from the surface to the bottom, would be reduced to the point of congelation, and would consequently be converted into a solid mass, all the organised tribes inhabiting the waters being destroyed.

The existence of a temperature of maximum density at a point of the thermometric scale above the point of congelation of water, combined with the very feeble conducting power of water, whether in the liquid or solid state, renders such a catastrophe impossible.

37. The air is subject to less extreme changes of temperature at sea than on land. Thus, in the torrid zone, while the temperature on land suffers a diurnal variation amounting to 10°, the extreme diurnal variation at sea does not exceed 3½°. In the temperate zone the diurnal variation at sea is limited generally to about 5½°, while on continents it is very various and everywhere considerable. In different parts of Europe it varies from 20° to 25°.

At sea as on land the time of lowest temperature is that of sunrise, but the time of greatest heat is about noon, while on land it is at two or three hours after noon.

On comparing the temperature of the air at sea with the superficial temperature of the water, it has been found that between the tropics the air, when at its highest temperature, is warmer than the water, but that its mean diurnal temperature is lower than that of the water.

In latitudes between 25° and 50° the temperature of the air is

very rarely higher than that of the water, and in the polar regions the air is never found as warm as the surface of the water. It is, on the contrary, in general at a very much lower temperature.

38. Much uncertainty prevails as to the thermal phenomena manifested in the vast collections of water which cover the greater part of the surface of the globe. It appears, however, to be admitted that the currents caused by the difference of the pressures of strata at the same level in the polar and equatorial seas, produce an interchange of waters, which contributes in a great degree to moderate the extreme thermal effects of these regions, the current from the pole reducing the temperature of the equatorial waters, and that from the line raising the temperature of the polar waters and contributing to the fusion of the ice. A superficial current directed from the line towards the poles carries to the colder regions the heated waters of the tropics, while a counter current in the inferior strata carries from the poles towards the line the colder waters. Although the prevalence of these currents may be regarded as established, they are nevertheless modified, both in their intensity and direction, by a multitude of causes connected with the depth and form of the bottom, and the local influence of winds and tides.

39. The stupendous mass of water in the solid state which forms an eternal crust encasing the regions of the globe immediately around the poles, presents one of the grandest and most imposing classes of natural phenomena. The observations and researches of Captain Scoresby have supplied a great mass of valuable information in this department of physical geography.

40. Upon the coasts of Spitzbergen and Greenland vast fields of ice are found, the extent of which amounts to not less than twelve to fifteen hundred square miles, the thickness varying from twenty to twenty-five feet. The surface is sometimes so even that a sledge can run without difficulty for an hundred miles in the same direction. It is, however, in some places, on the contrary, as uneven as the surface of land, the masses of ice collecting in columns and eminences of a variety of forms, rising to heights of from twenty to thirty feet, and presenting the most striking and picturesque appearances. These prodigious crystals sometimes exhibit gorgeous tints of greenish blue, resembling certain varieties of topaz, and sometimes this is varied by a thick covering of snow upon their summits, which gives them the appearance of cliffs of chalk or white marble, marked by an endless variety of form and outline.

41. These vast ice-fields are sometimes suddenly broken, by the pressure of the subjacent waters, into fragments presenting a

surface of from 100 to 200 hundred square yards. These being dispersed, are carried in various directions by currents, and sometimes by the effect of intersecting currents they are brought into collision with a fearful crash. A ship, which might chance in such a case to be found between them could no more resist their force than could a glass vessel the effect of a cannon ball. Terrible disasters occur from time to time from this cause. It is by the effects of these currents upon the floating masses of broken ice that these seas are opened to the polar navigators. It is thus that whalers are enabled to reach the parallels from 70° to 80°, which are the favourite resort of those monsters of the deep which they pursue.

42. Sometimes after such collisions new icebergs arise from the fragments which are heaped one upon another, "Pelion on Ossa," more stupendous still than those which have been broken. In such cases the masses which result assume forms infinitely various, rising often to an elevation of thirty to fifty feet above the surface of the water; and since the weight of ice is about four-fifths of the weight of its own bulk of water, it follows that the magnitude of these masses submerged is four times as great as that which is above the surface. The total height of these floating icebergs, therefore, including the part submerged, must be from 150 to 250 feet.

43. It happens sometimes that two such icebergs resting on the extremities of a fragment of ice 100 or 120 feet in length, keep it sunk at a certain depth below the surface of the water. A vessel in such cases may sail between the icebergs and over the sunken ice; but such a course is attended with the greatest danger, for if any accidental cause should detach either of the icebergs which keep down the intermediate mass while the ship is passing, the latter by its buoyancy will rise above the surface, and will throw up the ship with irresistible force.

44. Icebergs are observed in Baffin's Bay of much greater magnitude than off the coast of Greenland. They rise there frequently to the height of 100 to 130 feet above the surface, and their total height, including the part immersed, must therefore amount to 500 or 650 feet. These masses appear generally of a beautiful blue colour, and having all the transparency of crystals. During the summer months, when the sun in these high latitudes never sets, a superficial fusion is produced, which causes immense cascades, which, descending from their summit and increasing in volume as they descend, are precipitated into the sea in parabolic curves. Sometimes, on the approach of the cold season, these liquid arches are seized and solidified by the intensity of the cold without losing their form, and seem as if caught in their flight between the brink from which they were projected and the surface,

and suddenly congealed. These stupendous arches, however, do not always possess cohesion in proportion to their weight, and after augmenting in volume to a certain limit, sink under their weight, and, breaking with a terrific crash, fall into the sea.

45. The depth of the seas off the coast of Greenland is not considerable. Whales, being harpooned, often plunge in their agony to the bottom, carrying with them the harpoon and line attached to it. When they float they bear upon their bodies evidence of having reached the bottom by the impression they retain of it, and the length of line they carry with them in such cases shows that depth does not exceed 3000 or 4000 feet. About the middle of the space between Spitzbergen and Greenland the soundings have reached 8000 feet without finding bottom.

46. The degree of cold of the polar regions, like the temperature of all other parts of the globe, depends on the extent and depth of the seas. If there be extensive tracts of surface not covered by water, or covered only by a small depth, the influence of the water in moderating and equalising the temperature is greatly diminished. Hence it is that the temperature of the south polar regions is more moderate than that of the north. After passing the latitude of the New Orcades and the New Shetlands, which form a barrier of ice, the navigator enters an open sea, which, according to all appearance, extends to the pole. Much, however, still remains to be discovered respecting the physical condition of these regions.

TERRESTRIAL HEAT.

CHAPTER II.

47. Sources of external heat.—48. Solar heat.—49. Its quantity ascertained.—50. Heat at sun's surface.—51. Temperature of celestial spaces.—52. Quantity of heat supplied by them.—53. Summary of heat supplied.—54. Winds.—55. Produced by rarefaction and compression.—56. Sudden condensation of vapour.—57. Hurricanes.—58. Their cause.—59. Waterspouts.—60. Evaporation.—61. Saturation of air.—62. May arise from intermixing strata.—63. Effect of pressure.—64. Dew.—65. Hoar frost.—66. Artificial ice.—67. Fogs and clouds.—68. Rain.—69. Its quantity.—70. Snow.—71. Hail.—72. Hailstones.—73. Extraordinary hailstones.

47. WHATEVER may be the sources of internal heat, the globe of the earth would, after a certain time, be reduced to a state of absolute cold, if it did not receive from external sources the quantity of heat *necessary to repair* its losses. If the globe were

suspended in space, all other bodies from which heat could be supplied to it being removed, the heat which now pervades the earth and its surrounding atmosphere would be necessarily dissipated by radiation, and would thus escape into the infinite depths of space. The temperature of the atmosphere, and those of the successive strata, extending from the surface to the centre of the globe, would thus be continually and indefinitely diminished.

As no such fall of temperature takes place, and as, on the contrary, the mean temperature of the globe is maintained at an invariable standard, the variations incidental to season and climate being all periodical, and producing in their ultimate result a mutual compensation, it remains to be shown from what sources the heat is derived which maintains the mean temperature of the globe at this invariable standard, notwithstanding the large amount of heat which it loses by radiation into the surrounding space.

All the bodies of the material universe, which are distributed in countless numbers throughout the infinitude of space, are sources of heat, and centres from which that physical agent is radiated in all directions. The effect produced by the radiation of each of these diminishes in the same proportion as the square of its distance increases. The fixed stars are bodies analogous to our sun, and at distances so enormous that the effect of the radiation of any individual star is altogether insensible. When, however, it is considered that the multitude of these stars spread over the firmament is so prodigious that in some places many thousand are crowded together within a space no greater than that occupied by the disc of the full moon, it will not be matter of surprise that the feebleness of thermal influence, due to their immense distances, is compensated to a great extent by their countless number; and that, consequently, their calorific effects in those regions of space through which the earth passes in its annual course is, as will presently appear, not only far from being insensible, but is very little inferior to the calorific power of the sun itself.

We are, then, to consider the waste of heat which the earth suffers by radiation as repaired by the heat which it receives from two sources, the sun and the stellar universe; and it remains to explain what is the actual quantity of heat thus supplied to the earth, and what proportion of it is due to each of these causes.

48. An elaborate series of experiments were made by M. Pouillet, and concluded in 1838, with the view of obtaining, by means independent of all hypothesis as to the physical character of the sun, an estimate of the actual calorific power of that luminary. A detailed report of these observations and experiments, and an

elaborate analysis of the results derived from them, appeared in the Transactions of the Academy of Sciences of Paris for that year.

It would be incompatible with the elementary nature and the consequent limits of this work, to enter into the details of these researches. We shall, therefore, confine ourselves here briefly to state their results.

When the firmament is quite unclouded, the atmosphere absorbs about one-fourth of the heat of those solar rays which enter it vertically. A greater absorption takes place for rays which enter it obliquely, and the absorption is augmented in a certain ascertained proportion, with the increase of obliquity. It results from the analysis of the results obtained in the researches of M. Pouillet, that about forty per cent. of all the heat transmitted by the sun to the earth is absorbed by the atmosphere, and that consequently only sixty per cent. of this heat reaches the surface. It must, however, be observed that a part of the radiant heat, intercepted by the atmosphere, raising the temperature of the air, is afterwards transmitted, as well by radiation as by contact, from the atmosphere to the earth.

By means of direct observation and experiment made with instruments contrived by him, called *pyrheliometers*, by means of which the heat of the solar radiation was made to affect a known weight of water at a known temperature, M. Pouillet ascertained the actual quantity of heat which the solar rays would impart per minute to a surface of a given magnitude, on which they would fall vertically. This being determined, it was easy to calculate the quantity of heat imparted by the sun in a minute to the hemisphere of the earth which is presented to it, for that quantity is the same which would be imparted to the surface of the great circle which forms the base of that hemisphere, if the solar rays were incident perpendicularly upon it.

49. In this manner it was ascertained, that if the total quantity of heat which the earth receives from the sun in a year were uniformly diffused over all parts of the surface, and were completely absorbed in the fusion of a shell of ice encrusting the globe, it would be sufficient to liquefy a depth of 100 feet of such shell.

Since a cubic foot of ice weighs 54 lb., it follows that the average annual supply of heat received from the sun per square foot of the earth's surface would be sufficient to dissolve 5400 lb. weight of ice.

This fact being ascertained supplies the means of calculating the quantity of heat emitted from the surface of the sun, independently of any hypothesis respecting its physical constitution.

It is evident from the uniform calorific effects produced by the solar rays at the earth, while the sun revolves on its axis exposing successively every side to the earth in the course of about twenty-five days, that the calorific emanation from all parts of the solar surface is the same. Assuming this, then, it will follow, that the heat which the surface of a sphere surrounding the sun at the distance of the earth would receive would be so many times more than the heat received by the earth as the entire surface of such sphere would be greater than that part of it which the earth would occupy. The calculation of this is a simple problem of elementary geometry.

But such a spherical surface surrounding the sun and concentrical with it, would necessarily receive all the heat radiated by that luminary, and the result of the calculation proves that the quantity of heat emitted by the sun per minute is such as would suffice to dissolve a shell of ice enveloping the sun, and having a thickness of $38\frac{6}{10}$ feet; and that the heat emitted per day would dissolve such a shell, having a thickness of 55,748 feet, or about $10\frac{1}{2}$ miles.

50. The most powerful blast furnaces do not emit for a given extent of fire surface more than the seventh part of this quantity of heat. It must therefore be inferred that each square foot of the surface of the sun emits about seven times as much heat as is issued by a square foot of the fire surface of the fiercest blast furnace.

51. When the surface of the earth during the night is exposed to an unclouded sky, an interchange of heat takes place by radiation. It radiates a certain part of the heat which pervades it, and it receives, on the other hand, the heat radiated from two sources,—1st, from the strata of atmosphere, extending from the surface of the earth to the summit of the atmospheric column; and 2nd, from the celestial spaces, which lie outside this limit, and which receive their heat from the radiation of the countless numbers of suns which compose the stellar universe. M. Pouillet, by a series of ingeniously contrived experiments and observations, made with the aid of an apparatus contrived by him, called an *actinometer*, has been enabled to obtain an approximate estimate of the proportion of the heat received by the earth which is due to each of these two sources, and thereby to determine the actual temperature of the region of space through which the earth and planets move. The objects and limits of this work do not permit us to give the details of these researches, and we must therefore confine ourselves here to the statement of their results.

It appears from the observations, that the actual temperature of space is included between the minor limit of 315° and the major limit of 207° below the temperature of melting ice, or between

—283° and —175° Fahr. At what point between these limits the real temperature lies, is not yet satisfactorily ascertained, but M. Pouillet thinks that it cannot differ much from —224° Fahr.

52. It is proved from these results, that the quantity of heat imparted to the earth in a year, by the radiation of the celestial space, is such as would liquefy a spherical shell of ice, covering the entire surface of the earth, the thickness of which would be 85 feet, and that forty per cent. of this quantity is absorbed by the atmosphere.

Thus the total quantity of heat received annually by the earth is such as would liquefy a spherical shell of ice 185 feet thick, of which 100 feet are due to the sun, and 85 feet to the heat which emanates from the stellar universe.

The fact that the celestial spaces supply very little less heat to the earth annually than the sun, may appear strange, when the very low temperature of these spaces is considered, a temperature 180° lower than the cold of the pole during the presence of the sun. It must, however, be remembered that while the space from which the solar radiation emanates, is only that part of the firmament occupied by the disc of the sun, that from which the celestial radiation proceeds is the entire celestial sphere, the area of which is about five million times greater than the solar disc. It will therefore cease to create surprise, that the collective effect of an area so extensive should be little short of that of the sun.

The calorific effect due to the solar radiation, according to the calculations and observations of M. Pouillet, exceeds that which resulted from the formulæ of Poisson. These formulæ were obtained from the consideration of the variation of the temperature of the strata of the earth at different depths below the surface. M. Pouillet thinks that the results proceeding from the two methods would be brought into accordance if the influence of the atmosphere on solar heat, which, as appears from what has been explained, is very considerable, could be introduced in a more direct manner into Poisson's formulæ.

53. In fine, therefore, the researches of M. Pouillet give the following results, which must be received as mere approximations subject to correction by future observation:

1st. That the sun supplies the earth annually with as much heat as would liquefy 100 feet thick of ice covering the entire globe.

2nd. That the celestial spaces supply as much as would liquefy 85 feet thick.

3rd. That forty per cent of the one and the other supply is *absorbed by the atmosphere*, and sixty per cent received by the *earth*.

4th. That of the heat radiated by the earth, ninety per cent. is intercepted by the atmosphere, and ten per cent. dispersed in space.

5th. That the heat evolved on the surface of the sun in a day would liquefy a shell of ice 10½ miles thick, enveloping the sun, and the intensity of the solar fire is seven times greater than that of the fiercest blast furnace.

6th. That the temperature of space outside the atmosphere of the earth is 256° below that of melting ice.

7th. That the solar heat alone, constitutes only two-thirds of the entire quantity of heat supplied to the earth to repair its thermal losses by terrestrial radiation; and that without the heat supplied by stellar radiation, the temperature of the earth would fall to a point which would be incompatible with organic life.

54. No meteorological phenomenon has had so many observers, and there is none of which the theory is so little understood, as the winds. The art of navigation has produced in every seaman an observer, profoundly interested in the discovery of the laws which govern a class of phenomena, upon the knowledge of which depends not only his professional success but his personal security, and the lives and property committed to his charge.

The chief part of the knowledge which has been collected respecting the causes which produce these atmospheric currents is derived, nevertheless, much more from the comparison of the registers of observatories than from the practical experience of mariners.

55. Winds are propagated either by *compression* or by *rarefaction*. In the former case they are developed in the same direction in which they blow; in the latter case they are developed in the contrary direction. To render this intelligible, let us imagine a column of air included in a tube. If a piston inserted in one end of the tube be driven from the mouth inwards, the air contiguous to it will be compressed, and this portion of air will compress the succeeding portion, and so on; the compression being propagated from the end at which the piston enters toward the opposite end. The remote end being open, the air will flow in a current driven before the piston in the same direction in which the compression is propagated.

If we imagine, on the other hand, a piston inserted in the tube at some distance from its mouth, to be drawn outwards toward the mouth, the air behind it will expand into the space deserted by the piston, and a momentary rarefaction will be produced. The next portion of air will in like manner follow that which is next the piston, the rarefaction which begins at the piston being propagated backwards through the tube in a direction contrary to the

motion of the piston and that of the current of air which follows it.

What is here supposed to take place in the tube is exhibited on a larger scale in the atmosphere. Any physical cause which produces a compression of the atmosphere from north to south will produce a north wind; and any cause which produces a rarefaction from north to south will produce a south wind.

56. Of all the causes by which winds are produced, the most frequent is the sudden condensation of vapour suspended in the atmosphere. In general the atmosphere above us consists of a mixture of air properly so called, and water, either in the state of vapour, or in a vesicular state, the nature and origin of which has not yet been clearly ascertained. In either case its sudden conversion into the liquid state, and its consequent precipitation to the earth, leaves the space it occupied in the atmosphere a vacuum, and a corresponding rarefaction of the air previously mixed with the vapour ensues. The adjacent strata immediately rush in to re-establish the equilibrium of pneumatic pressure, and winds are consequently produced.

The propagation of winds by rarefaction manifested in directions contrary to that of the winds themselves, is common in the North of Europe. Wargentin gives various examples of this. When a west wind springs up, it is felt, he observes, at Moscow before it reaches Abo, although the latter city is four hundred leagues west of Moscow, and it does not reach Sweden until after it has passed over Finland.

57. The intertropical regions are the theatre of hurricanes. It is there only that these atmospheric commotions are displayed in all their terrors. In the temperate zones tempests are not only more rare in their occurrence but much less violent in their force. In the circumpolar zone the winds seldom acquire the force which would justify the title of a storm.

The hurricanes of the warm climates spread over a considerable width, and extend through a still more considerable length. Some are recorded which have swept over a distance of four or five hundred leagues with a nearly uniform violence.

It is only by recounting the effects produced by these vast commotions of the atmospheric ocean, that any estimate can be formed of the force which air, attenuated and light as that fluid is, may acquire when a great velocity is given to it. In hurricanes such as that which took place at Guadaloupe on the 25th July, 1825, houses the most solidly constructed were overthrown. A new building erected in the most durable manner by the government was razed to the ground. Tiles carried from the roof were projected against thick doors with such force as to pass through them like a cannon

ball. A plank of wood $3\frac{1}{2}$ feet long, 9 inches wide, and an inch thick, was projected with such force as to cut through a branch of palm wood 18 inches in diameter. A piece of wood 15 feet long and 8 inches square in its cross section, was projected upon a hard paved road, and buried to a depth of more than three feet in it. A strong iron gate in front of the governor's house was carried away, and three twenty-four pounders erected on the fort were dismounted.

58. These effects, prodigious as they are, all arise from mechanical causes. There is no agent engaged in hurricanes more subtle than the mechanical force of air in motion, and since the weight and density of the air suffer no important change, the vast momentum manifested by such effects as those described above, must be ascribed altogether to the extraordinary velocity imparted to the air by the magnitude of the local vacuum produced, as already stated, by the sudden condensation of vapour. To form some approximate estimate of this it may be observed that, in the inter-tropical regions, a fall of rain often takes place over a vast extent of surface, sufficient in quantity to cover it with a stratum of water more than an inch in depth. If such a fall of rain were to take place over the extent of a hundred square leagues, as sometimes happens, the vapour from which such a quantity of liquid would be produced by condensation would, at the temperature of only 50°, occupy a volume of 100000 times greater than that of the liquid: and, consequently, in the atmosphere over the surface of 100 square leagues it would fill a space 9000 feet, or nearly two miles in height. The extent of the vacuum produced by its condensation would be a volume nearly equal to 200 cubic miles, or to the volume of a column whose base is a square mile and whose height is 200 miles.

59. The phenomena, called water or land spouts according as they are manifested at sea or on land, consist apparently of dense masses of aqueous vapour and air, having at once a gyratory and progressive motion, and resembling in form a conical cloud, the base of which is presented upwards, and the vertex of which generally rests upon the ground, but sometimes assumes a contrary position. This phenomenon is attended with a sound like that of a waggon rolling on a rough pavement.

Violent mechanical effects sometimes attend these meteors. Large trees torn up by the roots, stripped of their leaves, and exhibiting all the appearances of having been struck by lightning, are projected to great distances. Houses are often thrown down, unroofed, and otherwise injured or destroyed, when they lie in the course of these meteors. Rain, hail, and frequently globes of fire, like the ball lightning, also accompany them.

The various appearances exhibited by water-spouts are represented in fig. 1.

No satisfactory theory has yet connected these phenomena with the general laws of physics.

60. If the surface of a sea, lake, or other large collection of water were exposed to the atmosphere consisting of pure air without any admixture of vapour, evaporation would immediately commence, and the vapour developed at the surface of the water would ascend into and mix with the atmosphere. The pressure of the atmosphere would then be the sum of the pressures of the atmosphere, properly so called, and of the vapour suspended in it, since neither of these elastic fluids can augment or diminish the pressure of the other.

Fig. 1.

The vapour developed from the surface of the water thus mingling with the atmosphere, acquires a common temperature with it. This vapour, therefore, receiving thus from the air with which it is intermixed more or less heat, after having passed into the vaporous state, is *superheated vapour*. It has, therefore, a greater temperature than that which corresponds to its density, or, what is the same, it has a less density than that which corresponds to its temperature. Such vapour may therefore lose temperature to a certain extent without being condensed.

61. But if the same atmosphere continue to be suspended over the surface of water, the process of evaporation being continued, the quantity of vapour which rises into the air and mingles with it will be continually increased until it acquires the greatest density which is compatible with its temperature. Evaporation must then cease, and the air is said to be *saturated* with vapour.

If the temperature of the air in such case rise, evaporation will recommence and will continue until the vapour shall acquire the greatest density compatible with the increased temperature, and will then cease, the air being, as before, *saturated*.

But if the temperature fall, the greatest density of vapour compatible with it being less than at the higher temperature, a part of the vapour must be condensed, and this condensation must continue until the vapour suspended in the air shall be reduced to that state of density which is the greatest compatible with the reduced temperature.

A fluid so light and mobile as the atmosphere, can never remain long in a state of repose, and the column of air suspended over the surface of any collection of water however extensive, is subject to frequent change. In general, therefore, before any such portion of the atmosphere becomes saturated by evaporation, it is removed and replaced by another portion. It happens, consequently, that the atmosphere rarely becomes saturated by the immediate effect of evaporation.

62. The state of saturation is, however, often attained either by loss of temperature, or by the intermixture of strata of air of different temperatures and differently charged with vapours. Thus, if air which is below the point of saturation suffer a loss of heat, its temperature may fall to that point which is the highest compatible with the density of the vapour actually suspended in it. The air will then become saturated, not by receiving any increased quantity of vapour, but by losing that caloric by which the vapour it contained was previously *superheated.*

If two strata of air at different temperatures, and both charged with vapour to a point below saturation, be intermingled, they will take an intermediate temperature, that which had the higher temperature imparting a portion of its heat to that which had a lower temperature. The vapour with which they were previously charged will likewise be intermixed and reduced to the common temperature. Now, in this case it may happen that the common temperature to which the entire mass is reduced, after intermixture, shall be either equal to or less than the greatest temperature compatible with the density of the vapour in the mass of air thus mixed. If it be equal to that temperature, the mass of air after intermixture will be *saturated*, though the strata before intermixture were both below saturation; and if less, condensation must take place until the density of the vapour suspended in the mixture be reduced to the greatest density compatible with the temperature.

It might be supposed that air and vapour being mixed together without combining chemically, would arrange themselves in strata, the lighter floating above the heavier as oil floats above water. This statical law, however, which prevails in liquids, is in the case of elastic fluids subject to important qualifications. The latter class of fluids have a tendency to intermingle and diffuse themselves through and among each other in opposition to their specific gravities. Thus if a stratum of hydrogen, the lightest of the gases, rest upon a stratum of carbonic acid, which is the *heaviest*, they will by slow degrees intermingle, a part of the *hydrogen* descending among the carbonic acid, and a part of the *carbonic acid* ascending among the hydrogen, and this will continue

until the mixture becomes perfectly uniform, every part of it containing the two gases in the proportion of their entire quantities.

The same law prevails in the case of vapours mixed with gases; and thus may be explained the fact, that although the aqueous vapour suspended in the air, and having the same temperature, is always lighter bulk for bulk than the air, it does not ascend to the upper strata of the atmosphere, but is uniformly diffused through it.

63. It may be stated generally, that the effect of a column of air superposed upon the surface of water is only to retard, but not either to prevent or diminish, the evaporation. The same quantity of vapour will be developed as would be produced at the same temperature if no air were superposed on the water; but while in the latter case the entire quantity of vapour would be developed instantaneously, it is produced gradually, and completed only after a certain interval of time when the air is present. The quantity of vapour developed, and its density and pressure, are however exactly the same, whether the space through which it is diffused be a vacuum, or be filled by air, no matter what the density of the air may be. The properties of the air, therefore, neither modify nor are modified by those of the vapour which is diffused through it.

Since, at the same temperature and pressure, the density of the vapour of water is less than that of air in the ratio of 5 to 8, it follows that when air becomes charged with vapour of its own temperature, the volume will be augmented, but the density diminished. If a certain volume of air weigh 8 grains, an equal volume of vapour will weigh 5 grains, the two volumes mixed together will weigh 13 grains, and, consequently, an equal volume of the mixture will weigh 6½ grains. In this case, therefore, the density of the air charged with vapour is less than the density of dry air of the same temperature in the ratio of 6½ to 8.

64. The evaporation produced during the day by the action of solar heat on the surface of water, and on all bodies charged with moisture, causes the atmosphere at the time of sunset to be more or less charged with vapour, especially in the warm season. On hot days, and in the absence of winds, the atmosphere at sunset is generally at or near the point of saturation.

Immediately after sunset the temperature of the air falls. If it were previously in a state of saturation condensation must ensue, which will be considerable if the heat of the day and the consequent change of temperature after sunset be great. In such case, the vapour condensed often assumes the appearance of a fine

rain or mist taking the liquid form before its actual deposition on the surface.

The deposition of dew, however, also takes place even where the atmosphere is not reduced to its point of saturation. When the firmament is unclouded after sunset, all objects which are good radiators of heat, among which the foliage and flowers of vegetables are the foremost, lose by radiation the heat which they had received before sunset without receiving any heat from the firmament sufficient to replace it. The temperature of such objects, therefore, falls much below that of the air, on which they produce an effect precisely similar to that which a glass of very cold water produces when exposed to a warm atmosphere charged with vapour. The air contiguous to their surface being reduced to the dew point by contact with them, a part of the vapour which it holds in suspension is condensed, and collects upon them in the form of dew.

It follows from this reasoning, that the dew produced by the fall of temperature of the air below the point of saturation will be deposited equally and indifferently on the surfaces of all objects exposed in the open air, but that which is produced by the loss of temperature of objects which radiate freely, will only be deposited on those surfaces which are good radiators. Foreign writers on physics accordingly class these depositions as different phenomena, the former being called by French meteorologists *serein*, and the latter *rosée* or dew. We are not aware that there is in English any term corresponding to *serein*.

Dew will fail to be deposited even on objects which are good radiators, when the firmament is clouded. For although heat be radiated as abundantly from objects on the surface of the earth as when the sky is unclouded, yet the clouds being also good radiators, transmit heat, which being absorbed by the bodies on the earth, compensates for the heat they lose by radiation, and prevents their temperature from falling so much below that of the air as to produce the condensation of vapour in contact with them.

Wind also prevents the deposition of dew by carrying off the air from contact with the surface of the cold object before condensation has time to take place. Meanwhile by the contact of succeeding portions of air, the radiator recovers its temperature.

In general, therefore, the conditions necessary to insure the deposition of dew is, 1st, a warm day to charge the air with vapour; 2nd, an unclouded night; 3rd, a calm atmosphere; and, 4th, objects exposed to it which are good radiators of heat.

In the close and sheltered streets of cities the deposition of dew is rarely observed, because there the objects are necessarily

exposed to each other's influence, and an interchange of heat by radiation takes place so as to maintain their temperature; besides which, the objects found there are not as strong radiators as the foliage and flowers of vegetables.

65. When the cold which follows the condensation of vapour falls below 32°, what would otherwise be DEW becomes HOAR FROST. For the same reason that dew is deposited when the temperature of the air is above the point of saturation, hoar frost may be manifested when the temperature of the air is many degrees above the point of congelation; for in this case, as in that of dew, the objects on which the hoar frost collects lose so much heat by their strong radiation, that while the atmosphere may be above 40° they will fall below 32°. In such cases, a dew is first deposited upon them which soon congeals, and forms the needles and crystals with which every observer is familiar.

The hoar frost is sparingly or not at all formed upon the naked earth, or on stones or wood, while it is profusely collected on leaves and flowers. The latter are strong, the former feeble radiators.

Glass is a good radiator. The panes of a window fall during the night to a temperature below 32°, although the air of the room be at a much higher temperature. Condensation and a profuse deposition of moisture takes place on their inner surfaces, which soon congeals and exhibits the crystallised coating so often witnessed.

The frosts of spring and autumn, which so frequently are attended with injury to the crops of the farmer and gardener, proceed generally not from the congelation of moisture deposited from the atmosphere, but from the congelation of their own proper moisture by the radiation of their temperature caused by the nocturnal radiation, which in other cases produces dew or hoar frost. The young buds of leaves and flowers in spring, and the grain and fruit in autumn, being reduced by radiation below 32°, while the atmosphere is many degrees above that temperature, the water which forms part of their composition is frozen, and blight ensues.

These principles, which serve to explain the cause of the evil, also suggest its remedy. It is only necessary to shelter the object from exposure to the unclouded sky, which may be done by matting, gauze, and various other expedients.

66. In tropical climates the principle of nocturnal radiation has supplied the means of the artificial production of ice. This process, which is conducted on a considerable scale in Bengal, where some establishments *for the purpose* employ several hundred men, *consists in placing water in* shallow pans of unglazed pottery in a

situation which is exposed to the clear sky and sheltered from currents of air. Evaporation is promoted by the porous quality of the pans which become soaked with water, and radiation takes place at the same time both from the water and the pans. Both these causes combine in lowering the temperature of the water in the pans, which congeals when it falls below 32°.

67. When the steam issuing from the surface of warm water ascends into air which is at a lower temperature, it is condensed, but the particles of water formed by such condensation are so minute, that they float in the air as would the minute particles of an extremely fine dust. These particles lose their transparency by reason of their minuteness, according to a general law of physical optics. The vapour of water is transparent and colourless. It is only when it loses the character and qualities of true vapour, that it acquires the cloudy and semi-opaque appearance just mentioned.

Fogs are nothing more than such condensed vapour produced from the surface of seas, lakes, or rivers, when the water has a higher temperature than the stratum of air which rests upon it. These fogs are more thick and frequent when the air, besides having a lower temperature than the water, is already saturated with vapour, because in that case all the vapour developed must be immediately condensed, whereas, if the air be not saturated, it will absorb more or less of the vapour which rises from the water.

Clouds are nothing but fogs suspended in the more elevated strata of the atmosphere. Clouds are most frequently produced by the intermixture of two strata of air, having different temperatures and differently charged with vapour, the mixture being supersaturated, and therefore being attended with partial condensation as already explained.

68. When condensation of vapour takes place in the upper strata of the atmosphere, a fog or mist is first produced, after which the aqueous particles coalescing form themselves in virtue of the attraction of cohesion into spherules, and fall by their gravity to the earth, producing the phenomenon of rain.

69. The quantity of rain which falls in a given time at a given place, is expressed by stating the depth which it would have if it were received upon a plane and level surface, into which no part of it would penetrate.

At Paris, the average annual quantity of rain which falls, obtained from observations continued for thirty years at the Observatory, is 23·6 inches. There is, however, considerable variation in the quantities from which this average is deduced; the smallest quantity observed being 16·9 inches, and the greatest 27·9 inches.

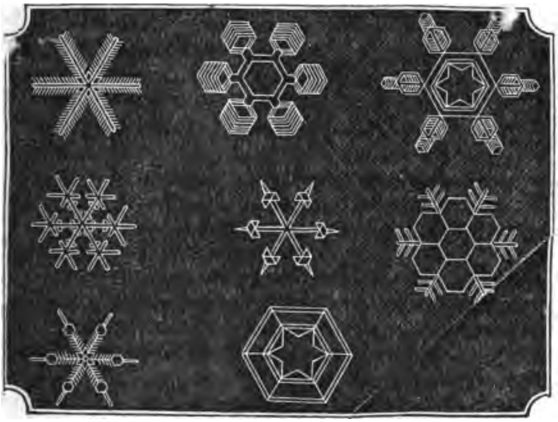
The greatest annual fall of rain is that observed at Maranham,

lat. 2½° S., which is stated by Humboldt to amount to 277 inches, more than double the annual quantity hitherto observed elsewhere.

70. The physical conditions which determine the production of snow are not ascertained. It is not known whether the flakes as they fall are immediately produced by the congelation of condensed vapour in the cloud whence they first proceed, or whether being at first minute particles of frozen vapour, they coalesce with other frozen particles in falling through the successive strata of the air, and thus finally attain the magnitude which they have on reaching the ground.

The only exact observations which have been made on snow refer to the forms of the crystals composing it, which Captain Scoresby has observed with great accuracy in his "Polar Voyages," and of which he has given drawings. The flakes appear to consist of fine needles, grouped with singular symmetry. A few of the most remarkable forms are represented in fig. 2.

Fig. 2.



71. The physical causes which produce that formidable scourge of the agriculturist hail are uncertain. Hypotheses have been advanced to explain it which are more or less plausible, but which do not fulfil the conditions that would entitle them to the place of physical causes.

72. In the absence of any satisfactory explanation of the phenomenon, it is important to ascertain with precision and certainty the circumstances which attend it, and the conditions under which it is produced.

It may then, in the first place, be considered as certain that the

formation of hail is an effect of sudden electrical changes in clouds charged with vapour; for there is no instance known of hail which is not either preceded or accompanied by thunder and lightning.

Before the fall of hail, during an interval more or less, but sometimes of several minutes' duration, a rattling noise is generally heard in the air, which has been compared to that produced by shaking violently bags of nuts.

Hail falls much more frequently by day than by night. Hail clouds have generally great extent and thickness, as is indicated by the obscuration they produce. They are observed also to have a peculiar colour, a gray having sometimes a reddish tint. Their form is also peculiar, their inferior surfaces having enormous protuberances, and their edges being indented and ragged.

These clouds are often at very low elevations. Observers on mountains very frequently see a hail cloud below them.

It appears, from an examination of the structure of hailstones, that at their centre there is generally an opaque nucleus, resembling the spongy snow that forms sleet. Round this is formed a congealed mass, which is semi-transparent. Sometimes this mass consists of a succession of layers or strata. These layers are sometimes all transparent, but in different degrees. Sometimes they are alternately opaque and semi-transparent.

73. Extraordinary reports of the magnitude of hailstones, which have fallen during storms so memorable as to find a place in general history, have come down from periods of antiquity more or less remote. According to the "Chronicles," a hailstorm occurred in the reign of Charlemagne, in which hailstones fell which measured fifteen feet in length by six feet in breadth, and eleven feet in thickness; and under the reign of Tippoo Saib, hailstones equal in magnitude to elephants are said to have fallen. Setting aside these and like recitals, as partaking rather of the character of fable than of history, we shall find sufficient to create astonishment in well authenticated observations on this subject.

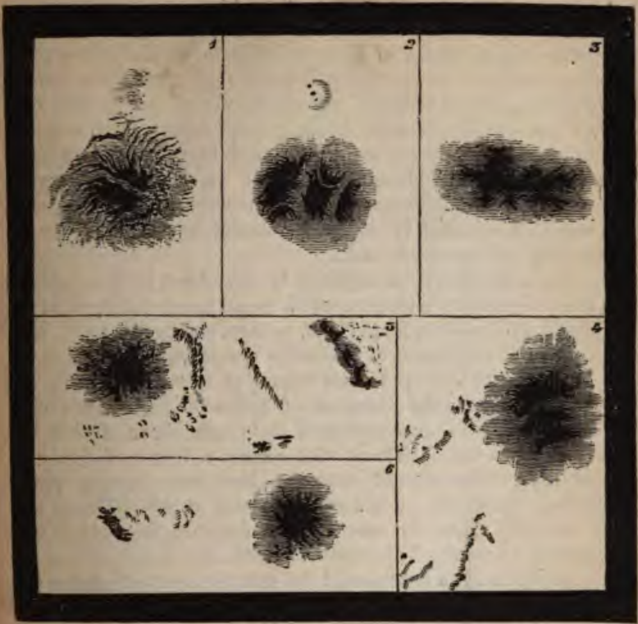
In a hailstorm which took place in Flintshire on the 9th April, 1697, Halley saw hailstones which weighed five ounces.

On the 4th May, 1697, Robert Taylor saw fall hailstones measuring fourteen inches in circumference.

In the storm which ravaged Como on 20th August, 1787, Volta saw hailstones which weighed nine ounces.

On 22nd May, 1822, Dr. Noggerath saw fall at Bonn hailstones which weighed from twelve to thirteen ounces.

It appears, therefore, certain that in different countries hailstorms have occurred in which stones weighing from half to three quarters of a pound have fallen.



SOLAR SPOTS OBSERVED IN 1826 AND 1828 BY MM. CAPOCCI AND PASTORFF.

Capocci—1. Sept. 29; 2. Sept. 2; 3. July 1, 1826.
Pastorff—4. Sept. 27, 1826; 5. May 21; 6. June 21, 1828.

THE SUN.

1. An object of great interest.—2. Its distance.—3. Magnitude.—4. Illustrations.—5. Its volume.—6. Mass or weight.—7. How ascertained.—8. Application of this principle.—9. Its density.—10. Form and rotation.—11. Determined by the appearance of spots.—12. Discovery of Solar spots.—13. Their great magnitude.—14. Their rapid changes.—15. Hypotheses to explain them.—16. They are excavations in the luminous coating.—17. Their prevalence varies.—18. Observations upon them.—19. Their dimensions.—20. Facules and Lucules.—21. Physical state of the Solar surface.—22. Luminous coating is gaseous.—23. Gaseous atmosphere outside it.—24. Effects of such an atmosphere on radiation.—25. Hypothesis of Sir J. Herschel.—26. Intensity of heat at Sun's surface.—27. Supposed source of heat.

1. Although perhaps the moon is the object among the heavenly bodies which presents the subject of most interesting inquiry to the world in general, yet, to the thoughtful and contemplative

mind, the sun is undoubtedly one of vastly superior interest. The sun—the fountain of light and life to a family of circumvolving worlds—the inexhaustible store of genial warmth by which the countless tribes of organised beings that people these globes are sustained—the physical bond whose predominating attraction gives stability, uniformity, and harmony, to the movements of the entire planetary system: to collect together in a brief compass the information which modern scientific research has supplied relating to this body, cannot be otherwise than an interesting and agreeable task.

2. When we direct our inquiries to any object in the heavens, the first questions which present themselves naturally to us are, "What is its distance, magnitude, motion, and position?" When we say that the distances of the bodies composing the solar system can be measured with the same degree of relative accuracy with which we ascertain the distances of bodies on the surface of the earth, those who are unaccustomed to investigations of this kind usually receive the statement with a certain degree of doubt and incredulity; they cannot conceive how such spaces can be accurately measured, or indeed measured at all. Thus, when they are told that the sun is at a distance from the earth amounting to nearly 100,000000 of miles, the mind revolts from the idea that such a space could be exactly ascertained and estimated. Yet, let us ask, why this difficulty? whence this incredulity? Is it because the distance thus measured is enormously great,—greater transcendently than any distance we are accustomed to contemplate upon our own globe? To this we reply that the magnitude of a distance or space does not constitute of itself any difficulty in its admeasurement. Nay, on the contrary, it is often the case that we are able to measure large distances with greater relative accuracy than small ones; this is frequently so in the surveys conducted on the surface of our own globe. If, then, the greatness of the magnitudes does not constitute of itself any difficulty, to what are we to ascribe the doubt entertained by the popular mind in regard to such measurement? It will, perhaps, be replied that the object, whose distance we claim to have measured, is inaccessible to us; that we cannot travel over the intermediate space, and therefore cannot be conceived to measure it. But again, let us ask whether this circumstance of being inaccessible constitutes any real difficulty in the measurement of the distance of an object? The military engineer, who directs his projectiles against the buildings within a town which is besieged, can, as we well know, level them so as to cause a shell to drop on any individual building which may have been chosen. To do this, he must know the exact distance of the building from

the mortar. Yet the building is inaccessible to him; the walls of the town, the fortifications, and perhaps a river, intervene. He finds, however, no difficulty in measuring the distance of this inaccessible building. To accomplish this, he lays down a space upon the ground he occupies, called the *base* line, from the extremities of which he takes the bearings or directions of the building in question. From these bearings, and from the length of the base line, he is enabled to calculate by the most simple principles of geometry and arithmetic the distance of the building in question. Now imagine the building in question to be the sun, and the base line to be the whole diameter of the globe of the earth, in what respect would the problem be altered? The building within the town is inaccessible—so is the sun; the base line of the engineer is exactly known—so is the diameter of the earth; the bearings of the building from the ends of the base line are known—so are the bearings of the sun's centre from the extremes of the earth's diameter. The problems are, in fact, identical; they differ in nothing except the accidental and unimportant circumstance of the magnitudes of the lines and angles that enter the question. In short, the measurement of distances of objects in the heavens is effected upon principles in all respects similar to those which govern the measurement of distances upon the earth; nor are they attended with a greater difficulty, or more extensive sources of error.

By such means of observation and calculation it has been ascertained that the sun's distance from the earth is a little less than an hundred millions of miles. Although such calculations supply results having surprising arithmetical accuracy, the ordinary student will always find it convenient to register in his memory the results in the nearest round numbers, and it is not easy to forget that the distance of the sun, the most important of all astronomical measurements, is very nearly an hundred millions of miles.

But while this round result is remembered, it will also be useful to explain the more exact numerical measure of this distance, and the limits of the error to which it is subject. The result of the most exact observations made upon the different bearings of lines drawn from opposite sides of the earth to the sun, gives as the distance of that luminary,

$$95{,}293452 \text{ miles},$$

and it has been proved that this result cannot be greater or less than the true distance by more than its three hundredth part. We are, therefore, enabled to affirm absolutely that the distance of the sun cannot be greater than

$$95{,}293452 + 317645 = 95{,}611097 \text{ miles};$$

or less than

$$95{,}293452 - 317645 = 94{,}975807 \text{ miles}.$$

Since the sun moves over 360° of the heavens in 365¼ days, its daily apparent motion must be 59′·14, or 3548″, which being about twice the sun's apparent diameter, it is easy to remember that the disk of the sun appears to move in the firmament daily over a space nearly equal to twice its own apparent diameter. Its hourly apparent motion is

$$\frac{3548''}{24}=147''\cdot 8.$$

3. Having explained the distance of the sun, let us now see how its magnitude can be ascertained. There is one general principle by which the magnitudes of all the heavenly bodies can be ascertained when their distance is known. This is, in fact, accomplished by the device of comparing them with some object of known magnitude and which at any known distance will have the same apparent size. As this is important, considered as a general principle applied to all objects in the heavens, it may not be uninteresting to develop it somewhat fully in its application to the present object, the sun.

The common observation of every one who directs his view to the heavens, will inform him of the fact that the sun and full moon appear to be of the same size. The mere effect of ordinary visual observation is, perhaps, enough to establish this; but if more be desired, instruments expressly adapted to measure the apparent magnitudes of objects may be applied. We are also confirmed in the fact by the consideration of the well-known phenomena of solar eclipses. A solar eclipse is produced by the interposition of the globe of the moon between the eye and the globe of the sun. The eclipse is said to be central when the centre of the moon is directly in line between the eye and the centre of the sun. When this takes place we find that the globe of the moon generally covers pretty exactly that of the sun. Owing, however, to a slight variation in the apparent size of these bodies, from a cause that we shall explain on another occasion, the moon at one time a little more than covers the sun, and at another time a little less. In short, the average apparent magnitudes of these bodies are the same, the one exactly covering or concealing the other.

But we have already stated that the distance of the moon is only a quarter of a million of miles. And since that of the sun is an hundred millions of miles, it appears that the distance of the sun is four hundred times greater than that of the moon; yet these two globes appear to the eye to be of the same magnitude. The sun, notwithstanding its being four hundred times farther off, appears just as large as the moon. What, then, are we to infer respecting its real magnitude? If the sun were really

equal in magnitude to the moon, it would assuredly appear four hundred times less at four hundred times a greater distance: but since at that greater distance it does not appear less or greater, but of the same magnitude, the irresistible conclusion, level to the apprehension of any understanding, is, that the sun must in reality be four hundred times greater in its diameter than the moon. If it were less, at four hundred times the moon's distance, it would appear less than that of the moon; if it were greater, at that distance it would appear greater. It follows, then, that whatever be the magnitude of the diameter of the moon, the diameter of the sun must assuredly be four hundred times greater. Now it has been ascertained by absolute measurement that the diameter of the moon measures about 2000 miles. If we multiply this by four hundred we shall obtain 800000 miles, which is, therefore, the diameter of the sun.

These calculations have been made roughly and in round numbers; more accurately, the diameter of the sun measures 882000 miles, but as we recommend the adoption of round numbers, we shall call the sun's diameter 900000 miles. Such is the stupendous mass placed in the centre of the system which, by its attraction, coerces the movements of the planets.

4. Such magnitudes and distances are so far beyond all the ordinary standards with which we are familiar, that the imagination is confounded and falls back upon itself after any effort to form a distinct conception of them. Let us see whether we cannot discover some expedient or some means of illustration by which a more distinct notion can be obtained of the distance and magnitude of this stupendous globe.

A railway-train moving at thirty-two miles an hour would take three millions of hours or an hundred and twenty-five thousand days, or three hundred and forty-two years and three months to move from the earth to the sun, supposing it to travel incessantly night and day for that time!

A cannon ball moves fifty times as fast as such a railway train. It would therefore move to the sun in a little less than seven years!

To give some idea of the dimensions of the sun we are to consider that having a diameter of 882000 miles, its circumference will be about 2,770000 miles. Such a railway-train would take nine years and ten months to travel round it.

We know that the moon revolves in a circle round the earth at the distance of nearly a quarter of a million of miles. Now let us suppose the earth to be placed at the centre of the sun. The distance of the outer surface of the sun from the centre of the earth would be 441000 miles. Now the circle in which the

moon revolves round the earth, is at a distance of 240000 miles from its centre, consequently it follows that the earth and moon would be not only contained within the globe of the sun, but the moon would be a couple of hundred thousand miles within the sun's surface.

5. But we have hitherto only spoken of the diameter of the sun; let us now consider its bulk. When we know the diameters of two globes we can always, by an easy operation of arithmetic, estimate their bulks. Thus, if one globe have a diameter double another, the bulk of the former will be eight times that of the latter. If the diameter be ten times greater, the bulk will be a thousand fold greater, and so on. Now we know that the diameter of the sun is about one hundred and twelve times greater than that of the earth, from which we infer, by the same principles of arithmetic, that the bulk of the sun must be very nearly one million four hundred thousand times the bulk of the earth. To make a globe like the sun, it would then be necessary to roll one million four hundred thousand globes like the earth into one! It is found by considering the bulks of the different planets, that if all the planets and satellites in the solar system were moulded into a single globe, that globe would still not exceed the five hundredth part the globe of the sun: in other words, the bulk of the sun is five hundred times greater than the aggregate bulk of all the rest of the bodies of the system.

6. The astronomer, however, is called upon to execute processes more difficult and yet no less indispensable than the mere measurement of distances and magnitudes. If we desire to know the quantities of matter composing those distant orbs, we must not merely measure their magnitudes and fathom their distances, but we must wing our flight, in imagination, across those vast distances which separate us from them and *weigh* their stupendous masses. If the popular student finds it difficult to believe and comprehend how we can measure distances and magnitudes such as those of the heavenly bodies, how much more will he be confounded when he is assured that we have at our disposal a balance of the most unerring exactitude in which we can place those vast orbs and poise them! The globe of the sun itself, transcendently greater than the earth and all the planets put together, is weighed with as great relative precision, as that with which the chemist in his analysis, estimates the weights of the constituents of the bodies which pass under his hands. As the general principles by which the weights of the bodies of the universe are ascertained is in spirit the same for all, it may be worth while here to explain the method, once for all, in its application to the sun.

7. When a body revolves in a circle, we know from common

and familiar experiments that it has a tendency to fly from the centre, which tendency is greater the more rapidly the body revolves and the greater its distance from the centre. The boy who whirls a stone in a sling is conscious of this physical truth. The stone, as it revolves, stretches the string with a certain definite force; this force is not in the gravity of the stone, for it would be equally manifested if the stone revolved in a horizontal plane. It is that tendency which we have just adverted to, and which is technically called centrifugal force. If you increase the velocity with which the stone is whirled round, you will find the string will be more and more tightly stretched, and you may augment the velocity to such an extent as to break the string. If you lengthen or shorten the string, preserving the same velocity of rotation, you will find that the tendency to stretch the string will be proportionally increased or diminished; in short, a fixed rule or *law*, as it is called, will be easily discovered by a series of simple experiments which will enable us to predict how much the string will be stretched, provided we know the distance of the revolving weight from the centre of the circle and the time it takes to make each revolution.

8. To apply this general principle, then, to the case before us, let it be considered that the moon in its monthly course revolves in a circle round the centre of the earth. We know its distance, and we know the time which it takes to make each revolution, we are therefore in a condition to declare with what force it would stretch a string, tying it to the centre of the earth. That the moon exercises such a force cannot then be doubted. But on what, it will be asked, is that force expended? There is no string, rod, or any other material or tangible connection between the moon and the centre of the earth. And yet the moon is held as firmly and steadily in its circular course round the earth, as if it were tied to the centre by a string. In the absence of the string there must then be some physical agency which plays its part; there must be something to resist that tendency which the string, if there, would have resisted. That *something* was discovered by Newton to be the attraction of the earth's GRAVITATION exercised upon the moon and holding the moon in its circular orbit, in the same manner that it would be held by the string which has been just described. As we know, by the simple mechanical law above explained, the force with which that string would be stretched by the moon in this case, we are enabled by the same principle to say what is the amount of attractive force which the earth exercises upon the moon to keep it in its monthly orbit.

In this manner, in general, we are enabled to estimate the force of attraction which a central mass exercises upon another bod-

revolving in a circle round it at a known distance, and in a known time.

While, on the one hand, we know the distance and time of the moon's revolution round the earth, we also know the distance and time of the earth's revolution round the sun. We are thus, allowing for the difference of the two distances, in a condition to compare the actual amount of attraction which the earth and the sun respectively exercise upon bodies revolving round them, and we find, accordingly, that the attraction exercised by the sun upon any body is greater than the attraction that would be exercised by the earth upon the same body in a like position, in the proportion of three hundred and fifty thousand to one. But as these attractions are, in fact, produced by the respective masses of matter composing the sun and the earth, it follows that the weight of the sun, or what is the same, the mass of matter composing it, is three hundred and fifty thousand times greater than the mass of matter or weight of the earth.

To make a globe as heavy as the sun, it would then be necessary to agglomerate into one three hundred and fifty thousand globes like the earth.

9. Having ascertained the weights and bulks of the bodies of the universe, we are in a condition to determine their densities, and thus to obtain some clue to a knowledge of their constituent materials. We have seen that while the bulk of the sun is about one million and four hundred thousand times greater than that of the earth, its weight is greater in the much less proportion of three hundred and fifty thousand to one. Let us see to what inference this leads in regard to the nature of the matter that composes the sun. If the materials of the sun were similar to those of the earth, its weight would necessarily be greater than that of the earth in the same proportion as its bulk, and in that case, of course, the weight of the sun would be one million and four hundred thousand times that of the earth. But it is not nearly so great as this; on the contrary, it is much less. Consequently, it follows that the constituent materials of the sun are lighter than those of the earth in the proportion of about four to one. The density of the sun is, therefore, about forty per cent. greater than that of water, and, consequently, the weight of the solar orb exceeds the weight of a globe of the same magnitude composed altogether of water, only in that proportion.

10. Although to minds unaccustomed to the rigour of scientific research, it might appear sufficiently evident, without further demonstration, that the sun is globular in its form, yet the more exact methods pursued in the investigation of physics demand that we should find more conclusive proof of the sphericity of the

solar orb than the mere fact that the disc of the sun is always circular. It is barely possible, however improbable, that a flat circular disc of matter, the face of which should always be presented to the earth, might be the form of the sun; and indeed there are a great variety of other forms which, by a particular arrangement of their motions, might present to the eye a circular appearance as well as a globe or sphere. To prove, then, that a body is globular, something more is necessary than the mere fact that it always appears circular.

11. When a telescope is directed to the sun, we discover upon it certain marks or spots, of which we shall speak more fully presently. We observe that these marks, while they preserve the same relative position with respect to each other, move regularly from one side of the sun to the other. They disappear, and continue to be invisible for a certain time, come into view again on the other side, and so once more pass over the sun's disc. This is an effect which would evidently be produced by marks on the surface of a globe, the globe itself revolving on an axis, and carrying these marks upon it. That this is the case, is abundantly proved by the fact that the periods of rotation for all these marks are found to be exactly the same, viz., about twenty-five and a half days. Such is, then, the time of rotation of the sun upon its axis, and that it is a globe remains no longer doubtful, since the globe is the only body which, while it revolves with a motion of rotation, could always present the circular appearance to the eye. The axis on which the sun revolves is very nearly perpendicular to the plane of the earth's orbit, and the motion of rotation of the sun upon the axis is in the same direction as the motion of the planets round the sun, that is to say, from west to east.

12. One of the earliest fruits of the invention of the telescope was the discovery of the spots upon the sun, and the examination of these has gradually led to a knowledge of the physical constitution of the centre of our system.

When we submit a solar spot to telescopical examination, we discover its appearance to be that of an intensely black irregularly-shaped patch, edged with a penumbral fringe, the brightness of the general surface of the sun gradually fading away into the blackness of the spot. When watched for a considerable time, it is found to undergo a gradual change in its form and magnitude; at first increasing in size, until it attains some definite limit of magnitude, when it ceases to increase, and soon begins, on the contrary, to diminish; and its diminution goes on gradually, until at length the bright edges closing in upon the dark patch, it dwindles first to a mere point, and finally disappears altogether.

The period which elapses between the formation of the spot, its gradual enlargement, subsequent diminution, and final disappearance, is very various. Some spots appear and disappear very rapidly, while others have lasted for weeks and even for months.

13. The magnitudes of the spots, and the velocities with which the matter composing their edges and fringes moves, as they increase and decrease, are on a scale proportionate to the dimensions of the orb of the sun itself. When it is considered that a space upon the sun's disc, the apparent breadth of which is only a minute, actually measures 27960 miles, and that spots have been frequently observed, the apparent length and breadth of which have exceeded 2′, the stupendous magnitude of the regions they occupy may be easily conceived.

14. The velocity with which the luminous matter at the edges of the spots occasionally moves, during the gradual increase or diminution of the spot, has been in some cases found to be enormous. A spot, the apparent breadth of which was 90″, was observed by Mayer to close in about 40 days. Now, the actual linear dimensions of such a spot must have been 41940 miles, and consequently, the average daily motion of the matter composing its edges must have been 1050 miles, a velocity equivalent to forty-four miles an hour.

15. Two, and only two, suppositions have been proposed to explain the spots. One supposes them to be scoriæ, or dark scales of incombustible matter, floating on the general surface of the sun. The other supposes them to be excavations in the luminous matter which coats the sun, the dark part of the spot being a part of the solid non-luminous nucleus of the sun. In this latter hypothesis it is assumed that the sun is a solid non-luminous globe, covered with a coating of a certain thickness of luminous matter.

That the spots are excavations, and not mere black patches on the surface, is proved by the following observations: If we select a spot which is at the centre of the sun's disc, having some definite form, such as that of a circle, and watch its changes of appearance, when, by the rotation of the sun, it is carried towards the edge, we find, first, that the circle becomes an oval. This, however, is what would be expected, even if the spot were a circular patch, inasmuch as a circle seen obliquely is foreshortened into an oval. But we find that as the spot moves towards the side of the sun's limb, the black patch gradually disappears, the penumbral fringe on the inside of the spot becomes invisible, while the penumbral fringe on the outside of the spot increases in apparent breadth, so that *when the spot* approaches the edge of the sun, the only part that *is visible is the* external penumbral fringe. Now, this is exactly *what would* occur if the spot were an excavation. The penumbral

fringe is produced by the shelving of the sides of the excavation, sloping down to its dark bottom. A. the spot is carried toward the edge of the sun, the height of the inner side is interposed between the eye and the bottom of the excavation, so as to conceal the latter from view. The surface of the inner shelving side also taking the direction of the line of vision or very nearly, diminishes in apparent breadth, and ceases to be visible, while the surface of the shelving side next the edge of the sun becoming nearly perpendicular to the line of vision, appears of its full breadth.

In short, all the variations of appearance which the spots undergo, as they are carried round by the rotation of the sun, changing their distances and positions with regard to the sun's centre, are exactly such as would be produced by an excavation, and not at all such as a dark patch on the solar surface would undergo.

16. It may be considered then as proved, that the spots on the sun are excavations; and that the apparent blackness is produced by the fact that the part constituting the dark portion of the spot is either a surface totally destitute of light, or by comparison so much less luminous than the general surface of the sun, as to appear black. This fact, combined with the appearance of the penumbral edges of the spots, has led to the supposition, advanced by Sir W. Herschel, which appears scarcely to admit of doubt, that the solid, opaque nucleus, or globe of the sun, is invested with at least two atmospheres, that which is next the sun being, like our own, non-luminous, and the superior one being that alone in which light and heat are evolved; at all events, whether these strata be in the gaseous state or not, the existence of two such, one placed above the other, the superior one being luminous, seems to be exempt from doubt.

We are not warranted in assuming that the black portion of the spots are surfaces really deprived of light, for the most intense artificial lights which can be produced, such, for example, as that of a piece of quicklime exposed to the action of the compound blow-pipe, when seen projected on the sun's disk, appear as dark as the spots themselves; an effect which must be ascribed to the infinitely superior splendour of the sun's light. All that can be legitimately inferred respecting the spots, then, is, not that they are destitute of light, but that they are incomparably less brilliant than the general surface of the sun.

17. The prevalence of spots on the sun's disk is both variable and irregular. Sometimes the disk will be completely divested of them, and will continue so *for weeks or* months; sometimes they will be *spread over certain parts of it* in profusion. Sometimes the spots *will be small, but numerous;* sometimes individual spots will

appear of vast extent; sometimes they will be manifested in groups, the penumbræ or fringes being in contact.

The duration of each spot is also subject to great and irregular variation. A spot has appeared and vanished in less than twenty-four hours, while some have maintained their appearance and position for nine or ten weeks, or during nearly three complete revolutions of the sun upon its axis.

A large spot has sometimes been observed suddenly to crumble into a great number of small ones.

The only circumstance of regularity which can be said to attend these remarkable phenomena is their position upon the sun. They are invariably confined to two moderately broad zones parallel to the solar equator, separated from it by a space several degrees in breadth. The equator itself, and this space which thus separates the macular zones, are absolutely divested of such phenomena.

18. Observations upon the appearances from which these inferences have been made, have been at various times made by astronomers, the most important being those of Sir William Herschel, Dr. Pastorff, Professor Capocci, and Sir J. Herschel, who have severally supplied drawings of their appearance, the general similarity of which, made at different places of observation, at very different times, and by different observers, offers a strong evidence of their authenticity.

In the figure at the head of this chapter, we have given copies of several of the most remarkable of these drawings.

19. The superficial dimensions of the several groups of spots observed on the sun on the 24th May, 1828, including the shelving sides, were calculated to be as follows:—

	Square Geog. miles.
Group A, principal spot	928,000000
Ditto, smaller spots	736,000000
Group B	296,000000
Group C	232,000000
Group D	304,000000
Total area	2496,000000

20. Independently of the dark spots just described, the luminous part of the solar disk is not uniformly bright. It presents a mottled appearance, which may be compared to that which would be presented by the undulated and agitated surface of an ocean of liquid fire, or to a stratum of luminous clouds of varying depth, and having an unequal surface, or the appearance produced by the slow subsidence of some flocculent chemical precipitates in a *transparent* fluid, when looked at perpendicularly from above. In the space immediately around the edges of the spots extensive

spaces are observed, also covered with strongly defined curved or branching streaks, more intensely luminous than the other parts of the disk, among which spots often break out. These several varieties in the intensity of the brightness of the disk have been differently designated by the terms *facules* and *lucules*. These appearances are generally more prevalent and strongly marked near the edges of the disk.

21. Various attempts have been made to ascertain by the direct test of observation, independently of conjecture or hypothesis, the physical state of the luminous matter which coats the globe of the sun, whether it be solid, liquid, or gaseous.

That it is not solid is admitted to be proved conclusively by its extraordinary mobility, as indicated by the rapid motion of the edges of the spots in closing; and it is contended that a fluid capable of moving at the rate of 44 miles per hour cannot be supposed to be liquid, an elastic fluid alone admitting of such a motion.

Arago has, however, suggested a physical test, by which it appears to be proved that this luminous matter must be gaseous; in short, that the sun must be invested with an ocean of flame, since flame is nothing more than aëriform fluid in a state of incandescence. This test proposed is based upon the properties of polarised light.

It has been proved that the light emitted from an incandescent body in the liquid or solid state, issuing in directions very oblique to the surface, even when the body emitting it is not smooth or polished, presents evident marks of polarisation, so that such a body, when viewed through a polariscopic telescope, will present two images in complementary colours. But, on the other hand, no signs of polarisation are discoverable, however oblique may be the direction in which the rays are emitted, if the luminous matter be flame.

The light proceeding from the disk of the sun has been accordingly submitted to this test. The rays proceeding from its borders evidently issue in a direction as oblique as possible to the surface, and therefore, under the condition most favourable to polarisation, if the luminous matter were liquid. Nevertheless, the borders of the double image produced by the polariscope show no signs whatever of complementary colours, both being equally white even at the very edges.

This test is only applicable to the luminous matter at or near the edge of the disk, because it is from this only that the rays issue with the necessary obliquity. But since the sun revolves on its axis, every *part of its surface* comes in succession to the edge of *the disk; and thus it follows* that the light emanating from every

part of it is in its natural or unpolarised state, even when issuing at the greatest obliquity; and, consequently, that the luminous matter is everywhere gaseous.

22. All the phenomena which have been here described, and others which our limits compel us to omit, are considered as giving a high degree of physical probability tc the hypothesis of Sir W. Herschel already noticed, in which the sun is considered to be a solid, opaque, non-luminous globe invested by two concentric strata of gaseous matter, the first, or that which rests immediately on the surface, being non-luminous, and the other, which floats upon the former, being luminous gas or flame. The relation and arrangement of these two fluid strata may be illustrated by our own atmosphere, supporting upon it a stratum of clouds. If such clouds were flame, the condition of our atmosphere would represent the two strata on the sun.

The spots in this hypothesis are explained by occasional openings in the luminous stratum by which parts of the opaque and non-luminous surface of the solid globe are disclosed. These partial openings may be compared to the openings in the clouds of our sky, by which the firmament is rendered partially visible.

23. Many circumstances supply indications of the existence of a gaseous atmosphere of great extent above the luminous matter which forms the visible surface of the sun. It is observed that the brightness of the solar disk is sensibly diminished towards its borders. This effect would be produced if it were surrounded by an imperfectly transparent atmosphere, whereas if no such gaseous medium surrounded it, the reverse of such an effect might be expected, since then the thickness of the luminous coating measured in the direction of the visual ray would be increased very rapidly in proceeding from the centre towards the edges. This gradual diminution of brightness in proceeding towards the borders of the solar disk has been noticed by many astronomers; but it was most clearly manifested in the series of observations made by Sir J. Herschel in 1837, so conclusively, indeed, as to leave no doubt whatever of its reality on the mind of that eminent observer. By projecting the image of the sun's disk on white paper by means of a good achromatic telescope, this diminution of light towards the borders was on that occasion rendered so apparent, that it appeared to him surprising that it should ever have been questioned.

But the most conclusive proofs of the existence of such an external atmosphere are supplied by certain phenomena observed on the occasion of total eclipses of the sun, which will be fully explained in another part of this series.

24. The heat generated by some undiscovered agency upon the

sun is dispersed through the surrounding space by radiation. If, as may be assumed, the rate at which this heat is generated be the same on all parts of the sun, and if, moreover, the radiation be equally free and unobstructed from all parts of its surface, it is evident that a uniform temperature must be everywhere maintained. But if, from any local cause, the radiation be more obstructed in some regions than in others, heat will accumulate in the former, and the local temperature will be more elevated there than where the radiation is more free.

But the only obstruction to free radiation from the sun must arise from the atmosphere with which to an height so enormous it is surrounded. If, however, this atmosphere have everywhere the same height and the same density, it will present the same obstruction to radiation, and the effective radiation which takes place through it, though more feeble than that which would be produced in its absence, is still uniform.

But since the sun has a motion of rotation on its axis in $25^{d.}\ 7^{h.}\ 48^{m.}$, its atmosphere, like that of the earth, must participate in that motion and the effects of centrifugal force upon matter so mobile: the equatorial zone being carried round with a velocity greater than 300 miles per second, while the polar zones are moved at a rate indefinitely slower, all the effects to which the spheroidal form of the earth is due will affect this fluid with an energy proportionate to its tenuity and mobility, the consequence of which will be that it will assume the form of an oblate spheroid, whose axis will be that of the sun's rotation. It will flow from the poles to the equator, and its height over the zones contiguous to the equator will be greater than over those contiguous to the poles, in a degree proportionate to the ellipticity of the atmospheric spheroid.

Now, if this reasoning be admitted, it will follow that the obstruction to radiation produced by the solar atmosphere is greatest over the equator, and gradually decreases in proceeding towards either pole. The accumulation of heat, and consequent elevation of temperature, is, therefore, greatest at the equator, and gradually decreases towards the poles, exactly as happens on the earth from other and different physical causes.

25. The effects of this inequality of temperature, combined with the rotation, upon the solar atmosphere, will of course be similar in their general character, and different only in degree from the phenomena produced by the like cause on the earth. Inferior currents will, as upon the earth, prevail towards the equator, and superior counter-currents towards the poles. The spots of the sun would, therefore, be assimilated to those tropical regions of the earth in which, for the moment, hurricanes and tornadoes prevail, the upper stratum which has come from the equator being

temporarily carried downwards, displacing by its force the strata of luminous matter beneath it (which may be conceived as forming an habitually tranquil limit between the opposite upper and under currents), the upper of course to a greater extent than the lower, and thus wholly or partially denuding the opaque surface of the sun below. Such processes cannot be unaccompanied by vorticose motions, which, left to themselves, die away by degrees, and dissipate, with this peculiarity, that their lower portions come to rest more speedily than their upper, by reason of the greater distance below, as well as the remoteness from the point of action, which lies in a higher region, so that their centre (as seen in our water-spouts, which are nothing but small tornadoes) appears to retreat upwards.*

Sir J. Herschel maintains that all this agrees perfectly with what is observed during the obliteration of the solar spots, which appear as if filled in by the collapse of their sides, the penumbra closing in upon the spot and disappearing afterwards.

It would have rendered this ingenious hypothesis still more satisfactory, if Sir J. Herschel had assigned a reason why the luminous and subjacent non-luminous atmosphere, both of which are assumed to be gaseous fluids, do not affect, in consequence of the rotation, the same spheroïdal form which he ascribes to the superior solar atmosphere.

26. It has been shown that the intensity of heat on the sun's surface must be seven times as great as that of the vivid ignition of the fuel in the strongest blast furnace. This power of solar light is also proved by the facility with which the calorific rays pass through glass. Herschel found, by experiments made with an actinometer, that 81·6 per cent of the calorific rays of the sun penetrate a sheet of plate-glass 0·12 inch thick, and that 85·9 per cent. of the rays which have passed through one such plate will pass through another.†

27. One of the most difficult questions connected with the physical condition of the sun, is the discovery of the agency to which its heat is due. To the hypothesis of combustion, or any other which involves the supposition of extensive chemical change in the constituents of the surface, there are insuperable difficulties. Conjecture is all that can be offered, in the absence of all data upon which reasoning can be based. Without any chemical change, heat may be indefinitely generated either by friction or by electric currents, and each of these causes have accordingly been suggested as a possible source of solar heat and light. According to the latter hypothesis, the sun would be a great ELECTRIC LIGHT in the centre of the system.

* *Herschel's* Cape Observations, p. 434. † Ibid., p. 133.

INTERIOR OF A ROOM IN THE ELECTRIC TELEGRAPH OFFICE, LOTHBURY.

THE ELECTRIC TELEGRAPH.

CHAPTER I.

1. Subjugation of the powers of nature to human uses.—2. Locomotion twenty years since.—3. Circulation of intelligence then.—4. Supposed prediction of succeeding improvements—Railway locomotion.—5. Electric telegraphy.—6. Fabrication of diamonds—sun pictures—gas-lighting—electro-metallurgy.—7. Such predictions would have been deemed incredible.—8. Electro-telegraphy the most incredible of all. —9. Remarkable experiment by Messrs. Leverrier and Lardner.—10. Velocity of electric current.—11. No limit to the celerity of telegraphy.—12. Physical character of electricity.—13. Not essential to the explanation of electro-telegraphy.—14. Electricity a subtle fluid.—15. Properties available for telegraphy.—16. Voltaic battery. —17 It is to the electric telegraph what the boiler is to the steam-engine.—18. Means of transmitting the fluid in required directions. —19. Conductors and insulators.—20. Conducting wires.—21. Voltaic battery.—22. Transmission and suspension of the current.—23. Current established by earth contact.—24. Theories of earth contact.—25. The return of the current through the earth.—26. Various bodies

evolve electricity.—27. Common plate battery of zinc and copper. —28. Why zinc and copper are preferred.—29. Charcoal substituted for copper.—30. Elements not essential.—31. Various chemical solutions used.—32. Daniel's constant battery.—33. Same modified by Pouillet.—34. Grove's and Bunsen's batteries.—35. Necessary to combine many elements.

1. Each succeeding age and generation leaves behind it a peculiar character, which stands out in relief upon its annals, and is associated with it for ever in the memory of posterity. One is signalised for the invention of gunpowder, another for that of printing; one is rendered memorable by the revival of letters, another by the reformation of religion; one is marked in history by the conquests of Napoleon, another is rendered illustrious by the discoveries of Newton.

If we are asked by what characteristic the present age will be marked in future records, we answer, by the miracles which have been wrought in the subjugation of the powers of the material world to the uses of the human race. In this respect no former epoch can approach to competition with it.

The author of some of the most popular fictions of the day has affirmed, that in adapting to his purpose the results of his personal observation on men and manners, he has not unfrequently found himself compelled to mitigate the real in order to bring it within the limits of the probable. No observer of the progress of the arts of life, at the present time, can fail to be struck with the prevalence of the same character in their results as that which compelled this writer to suppress the most wonderful of what had fallen under his eye, in order to bring his descriptions within the bounds of credibility.

2. Many are old enough to remember the time when persons, correspondence, and merchandise were transported from place to place in this country by stage-coaches, vans, and waggons. In those days the fast-coach, with its team of spanking blood-horses, and its bluff driver, with broad-brimmed hat and drab box-coat, from which a dozen capes were pendant, who "*handled the ribbons*" with such consummate art, could pick a fly from the ear of the off-leader, and turn into the gateway at Charing Cross with the precision of a geometrician, were the topics of the unbounded admiration of the traveller. Certain coaches obtained a special celebrity and favour with the public. We cannot forget how the eye of the traveller glistened when he mentioned the Brighton "Age," the Glasgow "Mail," the Shrewsbury "Wonder," or the Exeter "Defiance,"—the "Age," which made its trip in five hours, and the "Defiance," which acquired its fame by completing the journey between London and Exeter in less than thirty hours.

3. The rapid circulation of intelligence was also the boast of those times. How foreigners stared when told that the news of each afternoon formed a topic of conversation at tea-tables the same evening, twenty miles from London, and that the morning journals, still damp from the press, were served at breakfast within a radius of thirty miles, as early as the frequenters of the London clubs received them.

Now let us imagine that some profound thinker, deeply versed in the resources of Science at that epoch, were to have gravely predicted that the generation existing then and there would live to see all these admirable performances become obsolete, and consigned to the history of the past; that they would live to regard such vehicles as the "Age" and "Defiance" as clumsy expedients, and their celerity such as to satisfy those alone who were in a backward state of civilisation!

4. Let us imagine that such a person were to affirm that his contemporaries would live to see a coach like the "Defiance," making its trip between London and Exeter, not in thirty, but in five hours, and drawn, not by 200 blood-horses, but by a moderate sized stove and four bushels of coals!

5. Let us further imagine the same sagacious individual to predict that his contemporaries would live to see a building erected in the centre of London, in the cellars of which machinery would be provided for the fabrication of *artificial lightning*, which should be supplied *to order*, at a *fixed price*, in any quantity required, and of *any prescribed force;* that *conductors* would be carried from this building to all parts of the country, along which such *lightning* should be sent at will; that in the attics of this same building would be provided certain small instruments like barrel-organs or pianofortes; that by means of these instruments, the aforesaid lightning should, at the will and pleasure of those in charge of them, deliver messages at any part of Europe, from St. Petersburgh to Naples; and, in fine, that answers to such messages should be received instantaneously, and by like means: that in this same building offices should be provided, where any lady or gentleman might enter, at any hour, and for a few shillings send a message by *lightning* to Paris or Vienna, and by waiting for a few moments, receive an answer!

Might he not exclaim after the inspired author of the book of Job:—

"'Canst thou send lightnings, that they may go, and say unto thee, Here we are"!! xxxviii., 35.

But, suppose that his foresight should further enable him to pronounce *that means would* be invented by which any individual in *any one town or city of* Europe should be enabled to take in

his hand a pencil or pen, the point of which should be in any other town or city, no matter how distant, and should, with such pen or pencil, write or delineate in such distant place, such characters or designs as might please him, with as much promptitude and precision as if the paper to which these characters or designs were committed lay upon the table before him; or that an individual pulling a string at London should ring a bell at Vienna, or holding a match at St. Petersburgh should discharge a cannon at Naples!

6. Suppose he should affirm that means would be discovered for converting charcoal into diamonds; that the light of the sun would be compelled, without the intervention of the human hand, to make a portrait or a picture, with a fidelity, truth and precision, with which the productions of the most exalted artistic skill would not bear comparison; and that this picture should be produced and completed in its most minute details in a few seconds—nay, even in the fraction of a second; that candles and lamps would be superseded by flame manufactured on a large scale in the suburbs of cities, and distributed for use in pipes, carried under the streets, and into the houses and other buildings to be illuminated; and that the precious and other metals being dissolved in liquids, would form themselves into the articles of ornament and use by a spontaneous process, and without the intervention of human labour!!

No authority however exalted, no attainments however profound, no reputation however respected, could have saved the individual rash enough to have given utterance to such predictions some forty years ago, from being regarded as labouring under intellectual derangement. Yet all these things have not only come to pass, but the contemplation of many of them has become so interwoven with our habits, that familiarity has blunted the edge of wonder.

7. Compared with all such realities, the illusions of oriental romance grow pale; fact stands higher than fiction in the scale of the marvellous; the feats of Aladdin are tame and dull; and the slaves of the lamp yield precedence to the spirits which preside over the battery and the boiler.

8. Of all the physical agents discovered by modern scientific research, the most fertile in its subserviency to the arts of life is incontestably electricity, and of all the applications of this subtle agent, that which is transcendently the most admirable in its effects, the most astonishing in its results, and the most important in its influence upon the social relations of mankind, and upon the spread of civilisation and the diffusion of knowledge, is the Electric Telegraph. No force of habit, however long continued,

no degree of familiarity can efface the sense of wonder which the effects of this most marvellous application of science excites.

9. Being at Paris some years ago, I was engaged to share with M. Leverrier, the celebrated astronomer, and some other men of science, in the superintendence of a series of experiments to be made before committees of the Legislative Assembly and of the Institute, with the view of testing the efficiency of certain telegraphic apparatus. On that occasion operating in a room at the Ministry of the Interior appropriated to the telegraphs, into which wires proceeding from various parts of France were brought, we dictated a message, consisting of about forty words, addressed to one of the clerks at the railway station at Valenciennes, a distance of 168 miles from Paris. This message was transmitted in two minutes and a half. An interval of about five minutes elapsed, during which, as it afterwards appeared, the clerk to whom the message was addressed was sent for. At the expiration of this interval the telegraph began to express the answer, which, consisting of about thirty-five words, was delivered and written out by the agent at the desk, in our presence, in two minutes. Thus, forty words were sent 168 miles and thirty-five words returned from the same distance, in the short space of four minutes and thirty seconds.

But surprising as this was, we soon afterwards witnessed, in the same room, a still more marvellous performance.

The following experiment was prepared and performed at the suggestion and under the direction of M. Leverrier and myself:—

Two wires, extending from the room in which we operated to Lille, were united at the latter place, so as to form one continuous wire, extending to Lille and back, making a total distance of 336 miles. This, however, not being deemed sufficient for the purpose, several coils of wire wrapped with silk were obtained, measuring in their total length 746 miles, and were joined to the extremity of the wire returning from Lille, thus making one continuous wire measuring 1082 miles. A message consisting of 282 words was then transmitted from one end of the wire. A pen attached to the other end immediately began to write the message on a sheet of paper moved under it by a simple mechanism, and the entire message was written in full in the presence of the Committee, each word being spelled completely and without abridgment, in *fifty-two seconds*, being at the average rate of *five words and four-tenths per second!*

By this instrument, therefore, it is practicable to transmit intelligence to a distance of upwards of 1000 miles, at the rate of 19500 words per hour!

The instrument would, therefore, transmit to a distance of 1000 miles, in the space of an hour, the contents of about forty pages of the book now in the hands of the reader!

But it must not be imagined, because we have here produced an example of the transmission of a despatch to a distance of 1000 miles, that any augmentation of that distance could cause any delay of practical importance.

10. Although the velocity of the electric current has not been very exactly measured, it has been established beyond all doubt that it is so great that to pass from any one point on the surface of the earth to any other, it would take no more than an inappreciable fraction of a second.

11. If, therefore, the despatch had been sent to a distance of twenty thousand miles instead of one thousand, its transmission would still have been instantaneous.

Such a despatch would fly many times round the earth between the two beats of a common clock, and would be written in full at the place of its destination more rapidly than it could be repeated by word of mouth. When such statements are made, do we not feel disposed to exclaim—

> "Are such things here as we do speak about?
> Or have we eaten of the insane root,
> That makes the reason prisoner?"

In its wildest flights the most exalted imagination would not have dared, even in fiction, to give utterance to these stubborn realities. Shakspeare only ventured to make his fairy

> "Put a girdle round the earth
> In forty minutes."

To have encircled it several times in a second, would have seemed too monstrous, even for Robin Goodfellow.

The curious and intelligent reader of these pages will scarcely be content, after the statement of facts so extraordinary, to remain lost in vacant astonishment at the power of science, without seeking to be informed of the manner in which the phenomena of nature have been thus wonderfully subdued to the uses of man. A very brief exposition will be enough to render intelligible the manner in which these miracles of science are wrought.

12. The World of Science is not agreed as to the physical character of Electricity. According to the opinion of some it is a fluid infinitely lighter and more subtle than the most attenuated and impalpable gas, capable of moving through space with a velocity commensurate with its subtleness and levity. Some regard this fluid as simple. Others contend that it is compound,

consisting of two simple fluids having antagonistic properties which when in combination neutralise each other, but which recover their activity by decomposition. Others again regard it not as a specific fluid which moves through space, but as a phenomenon analogous to sound, and think that it is only a series of undulations or vibrations that are propagated through a highly elastic medium which produce the various electrical effects just as the pulsations of the atmosphere produce all the effects of sound.

13. Happily these difficult discussions are not necessary to the clear comprehension of the laws which govern the phenomena, upon which electric telegraphy depends. It will nevertheless for the purposes of explanation be convenient to use a system of language, which implies the existence of a certain fluid which we shall call the electric fluid, capable of moving over certain bodies, and being obstructed or altogether stopped by others, and which by its presence or proximity produces certain definite effects, mechanical and chemical.

14. Whether the electric agency be or be not a material fluid for our present purpose is unimportant. It is enough that it comports itself as such, and that the properties or effects which we shall impute to it are such only as it is ascertained by observation and experiment to possess or produce.

15. However various the forms may be which invention has conferred upon electric telegraphs, their efficiency in all cases depends on our power to produce at will the following effects:—

1st. To produce or develop the electric fluid in any desired quantity, and of the necessary quality.

2nd. To transmit it with celerity to any required distance, without injuriously dissipating it.

3rd. To cause it upon its arrival at any assigned point to produce some sensible effects, which may serve the purpose of written or printed characters.

16. The electric fluid is deposited in a latent state in unlimited quantity in the earth, the waters, the atmosphere, and in all bodies upon the earth, whether solid, liquid, or gaseous. It is disengaged and rendered active by various causes, natural and artificial. The mutual friction of bodies, contact and pressure, the contiguity or contact of bodies having different temperatures, the chemical action of bodies one upon another, the action of magnetic bodies on each other, and on bodies susceptible of magnetism, are severally causes of the development of the electric fluid in greater or less quantity.

Founded upon these *phenomena*, various apparatus have been contrived, by means of which the electric fluid may be evolved

and collected in any desired quantity, and with any required intensity. Among these, that which has proved to be the most efficient for telegraphic purposes is the GALVANIC or VOLTAIC BATTERY.

17. This apparatus is to the electric telegraph what the boiler is to the steam-engine. It is the generator of the fluid by which the action of the telegraphic machine is produced and maintained. It supplies the fluid in any required quantity and of any desired intensity. As the boiler is supplied with expedients by which within practical limits the quantity and pressure of the steam may be varied, according to the exigences of the work to which the engine is applied, so the voltaic battery is provided with expedients by which the quantity and intensity of the electric fluid it evolves can be varied according to the distance to which the intelligence is to be transmitted; and the form, whether visible, oral, written, or printed, in which it is required to be delivered at the place of its destination.

18. The electric fluid being thus produced in sufficient quantity, it is necessary to provide adequate means of transmitting it to a distance without exposing it to any cause of injurious dissipation or waste.

If tubes or pipes could be constructed with sufficient facility and cheapness, through which the subtle fluid could flow, and which would be capable of confining it during its transit, this object would be attained. As the galvanic battery is analogous to the boiler, such tubes would be analogous in their form and functions to the steam-pipe of a steam-engine.

19. The construction of such means of transmission has been accomplished by means of the well-known property of the electric fluid, in virtue of which it is capable of passing freely over a certain class of bodies called CONDUCTORS, while its movement is arrested by another class of bodies called NON-CONDUCTORS or INSULATORS.

The most conspicuous examples of the former class are the metals; the most remarkable of the latter being resins, wax, glass, porcelain, silk, cotton, dry air, &c.

20. Now if a rod or wire of metal be coated with wax or wrapped with silk, the electric fluid will pass freely along the metal, in virtue of its character of a conductor; and its escape from the metal laterally will be prevented by the coating, in virtue of its character of an insulator.

The insulator in such cases is, so far as relates to the electricity, a real tube, inasmuch as the electric fluid passes through the metal included by the coating, in exactly the same manner as water or gas passes through the pipes which conduct it; with this

difference, however, that the electric fluid moves along the wire more freely, in an almost infinite proportion, than does either water or gas in the tubes which conduct them.

If, then, a wire, coated with a non-conducting substance, capable of resisting the vicissitudes of weather, were extended between any two distant points, one end of it being attached to one of the extremities of a galvanic battery, a stream of electricity would pass along the wire—*provided the other end of the wire were connected by a conductor with the other extremity of the battery.*

21. How the fluid transmitted to a distant station is made to produce the effects by which messages are expressed will be explained hereafter, meanwhile it will be necessary first to explain the form and principle of the voltaic batteries used for telegraphic operations, and secondly the expedients by which the current is transmitted and suspended, and turned in one or another direction at the will of the operator at the station from which despatches are transmitted.

To comprehend the principle of the voltaic battery, let us suppose that two strips cut, one Z Z from a sheet of zinc, and the other C C (fig. 1) from a sheet of copper, are immersed without touching each other in a vessel containing water slightly acidulated. To the upper edges P and N of the strips let two pieces of wire P *p* and N *n*, be soldered. In this state of the apparatus no development of the electric fluid will be manifested; but if the ends *p* and *n* of the wires be brought into contact, an electric current will set in, running on the wires from P, the point where the wire is soldered to the copper C C, to N, the point where the other wire is soldered to the zinc Z Z. This current will continue to flow so long as the ends *p* and *n* of the wires are kept in mutual contact, and no longer. The moment the ends *p* and *n* are separated, the current ceases.

Fig. 1.

22. The commencement of the current upon the contact of the wires, and its cessation upon their separation, are absolutely *instantaneous;* so much so, that if the ends *p* and *n* were brought into contact and separated a hundred times in a second, the flow and suspension of the current being simultaneous with the

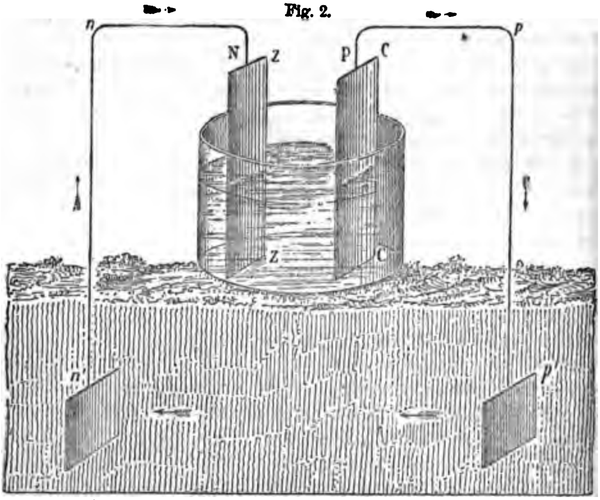
contacts and separations, would also take place a hundred times in a second.

The existence of the current established in this case is independent of the length of the wires P p and N n. Whether their length be 10 feet, 10 miles, or 100 miles, the current will still flow upon them when their extremities p and n are brought into contact. The only difference will be, that the intensity of the current will be less in the same proportion as the length of the wires is augmented.

23. There is another condition of great importance, whether regarded theoretically or practically, on which the current will be established and maintained.

Instead of bringing the wires P p and N n into contact, let them be continued downwards, as represented in fig. 2, and connected with two plates of metal p' and n', buried in the earth, or

Fig. 2.



with masses of metal or other good conducting body of any form whatever thus buried. In that case the current will be established as before, flowing along the wire soldered to the copper from P to p' and along that soldered to the zinc from n' to N.

Thus, in both cases the current starts from the copper, and, following the course of the wires, returns to the zinc. In the former case, however, it is continuous; but in the latter it is *apparently* broken, terminating at p', and recommencing at n'.

24. In the electric theories it is assumed that the course of the current, when it exists at all, must in all cases be continuous and unbroken from P to N, as it is in fact under the conditions represented in fig. 1, when the ends p and n are in contact. It is therefore assumed that in the case represented in fig. 2, the stratum of the earth which is interposed between p' and n' plays the part of a metallic wire joining these points, and that the current which arrives by the wire P $p\,p'$ at p' flows through the earth, as indicated by the arrow, to n', from whence it flows along the wire n' n N to N.

It is found also in this case that the existence of the current is independent of the lengths of the wires, which do not affect it otherwise than by diminishing its intensity. Whether the wires are 10 feet, 10 miles, or 100 miles in length, the current still flows from P to p' and returns from n' to N.

25. Thus, admitting the generally acknowledged principle that the stratum of the earth intervening between p' and n' plays the part of a conducting wire, uniting the ends p' and n' of the wires buried, it will follow that the current at p', though separated, as it may be, by a distance of several hundred miles from the point n' of its return to N, finds its way nevertheless through the earth unerringly and instantaneously to that point.

Of all the miracles of science, surely this is the most marvellous. A stream of electric fluid has its source in the cellars of the Central Electric Telegraphic Office, Lothbury, London. It flows under the streets of the great metropolis, and, passing on wires suspended over a zigzag series of railways, reaches Edinburgh, where it dips into the earth, and diffuses itself upon the buried plate. From that it takes flight through the crust of the earth, and *finds its own way* back to the cellars at Lothbury!!!

Instead of burying plates of metal, it would be sufficient to connect the wires at each end with the gas or water pipes, which, being conductors, would equally convey the fluid to the earth; and in this case, every telegraphic despatch which flies to Edinburgh along the wires which border the railways, would fly back, rushing to the gas-pipes which illuminate Edinburgh, from them through the crust of the earth to the gas-pipes which illuminate London, and from them home to the batteries in the cellars at Lothbury!

26. To derive all the necessary instruction from what has been explained above, it will be necessary to distinguish what is essential from what is merely optional, and which admits of modification or change without affecting the result.

27. It will be seen that the electric fluid is evolved by the combination of three bodies, the zinc, the copper, and the acidu-

lated solution in which they are immersed. The production of the current depends on the chemical action of the solution on the zinc. That metal being very susceptible of oxydation, decomposes the water which is in contact with it. One constituent of the water combining with the zinc, produces a compound called the oxyde of zinc, and this oxyde entering again into combination with the acid which the water holds in solution, forms a soluble salt. If the acid, for example, be sulphuric acid, this salt will be the sulphate of the oxyde of zinc, and as fast as it is produced it will be dissolved in the water in which the slips of metal are immersed.

Meanwhile, the copper not being as susceptible of chemical action as the zinc, remains comparatively unaffected by the solution; but the hydrogen evolved in the decomposition of the water collects upon its surface, after which it rises and escapes in bubbles at the surface of the solution.

It is to this chemical action upon the zinc that the production of the electric current is due. If a like action had taken place in the same degree on the copper, a similar and equally intense electric current would be produced in the opposite direction; and in that case the two currents would neutralise each other, and no electric effect would ensue.

From this it will be seen that the efficacy of the combination must be ascribed to the fact, that one of the two metals immersed in the solution is more oxydable than the other, and that the energy of the effect and the intensity of the current will be so much the greater as the susceptibility of oxydation of the one metal exceeds that of the other.

28. It appears, therefore, that the principle may be generalised, and that electricity will be developed, and a current produced by any two metals similarly placed, which are oxydable in different degrees.

Zinc being one of the most oxydable metals, and being also sufficiently cheap and abundant, is generally used by preference for voltaic combinations. Silver, gold, and platinum are severally less susceptible of oxydation, and of chemical action generally, than copper, and would therefore answer voltaic purposes better, but are excluded by their greater cost, and by the fact that copper is found sufficient for all practical purposes.

29. It is not, however, absolutely necessary that the inoxydable element C C of the combination should be a metal at all. It is only necessary that it be a good conductor of electricity. In certain voltaic combinations, charcoal properly solidified has therefore been substituted for copper, the solution being such as would produce a strong chemical action on copper.

30. In the above illustration, we have supposed that the

metallic elements of the combination are thin rectangular slips cut from sheet metal. The form, however, is in no manner essential to the production of the electric current. So long as the magnitude of the surfaces exposed to contact with the solution is the same, the current will have the same force. The pieces of metal may therefore have the form here supposed of thin rectangular plates, or they may be formed, as is often found convenient, into hollow cylinders, that of the copper being so much less in diameter than that of the zinc, that it is capable of being placed within it without mutual contact.

The simple arrangement first adopted by Volta consisted of two equal discs of metal, one of zinc, and the other of copper or silver, with a disc of cloth or bibulous card, soaked in an acid or saline solution, between them. These were usually laid, with their surfaces horizontal, one upon the other.

The late Dr. Wollaston proposed an arrangement, in which the copper plate was bent into two parallel plates, a space between them being left for the insertion of the zinc plate, the contact of the plates being prevented by the interposition of bits of cork or other non-conductor. The system thus combined was immersed in dilute acid, contained in a porcelain vessel.

Dr. Hare of Philadelphia contrived a voltaic arrangement, consisting of two metallic plates, one of zinc and the other of copper, of equal length, rolled together in the form of a spiral, a space of a quarter of an inch being left between them. They are maintained parallel without touching, by means of a wooden cross at top and bottom, in which notches are provided at proper distances, into which the plates are inserted, the two crosses having a common axis. This combination is let into a glass or porcelain cylindrical vessel of corresponding magnitude, containing the exciting liquid.

This arrangement has the great advantage of providing a very considerable electro-motive surface with a very small volume.

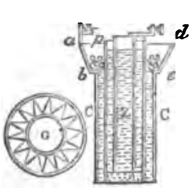
The exciting liquid recommended for these batteries when great power is desired, is a solution in water of $2\frac{1}{4}$ per cent. of sulphuric, and 2 per cent. of nitric acid. A less intense but more durable action may be obtained by a solution of common salt, or of 3 to 5 per cent. of sulphuric acid only.

31. It is not essential that the water in which the metals are immersed be acidulated, as we have supposed, by sulphuric acid. Any acid which will promote the oxydation of the zinc without affecting the copper will answer. Nor is it indeed necessary that any acid whatever be used. A saline solution is often found more convenient. Thus common salt dissolved in the water will produce the desired effect.

Of the various voltaic combinations which have been applied in scientific researches, four only have been found available to any considerable extent in the working of electric telegraphs, the zinc and copper plate combination described above, Daniel's constant battery, Grove's battery, Bunsen's modification of it, and the magneto-electric apparatus.

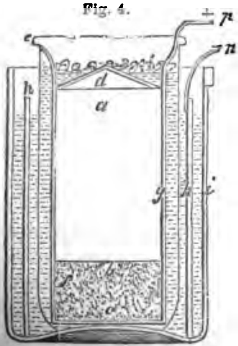
32. Daniel's combination, which is extensively used in working the telegraphs on the continent, consists of a copper cylindrical vessel c c, fig. 3, widening near the top *a d*. In this is placed a cylindrical vessel of unglazed porcelain *p*. In this latter is placed the hollow cylinder of zinc z, already described. The space between the copper and porcelain vessels is filled with a saturated solution of the sulphate of copper, which is maintained in a state of saturation by crystals of the salt placed in the wide cup *a b c d*, in the bottom of which is a grating composed of wire carried in a zigzag direction between two concentric rings, as represented in plan at G. The vessel *p*, containing the zinc, is filled with a solution of sulphuric acid, containing from 10 to 25 per cent. of acid when greater electro-motive power is required, and from 1 to 4 per cent. when more moderate action is sufficient.

Fig. 3.



33. The following modification of Daniel's system was adopted by M. Pouillet in his experimental researches, and is the form and arrangement used in France for the telegraphs. A hollow cylinder *a*, fig. 4, of thin copper, is ballasted with sand *b*, having a flat bottom *c*, and a conical top *d*. Above this cone the sides of the copper cylinders are continued, and terminate in a flange *e*. Between this flange and the base of the cone, and near the base, is a ring of holes. This copper vessel is placed in a bladder which fits it loosely like a glove, and is tied round the neck under the flange *e*. The saturated solution of the sulphate of copper is poured into the cup above the cone, and, flowing through the ring of holes, fills the space between the bladder and the copper vessel. It is maintained in its state of saturation by crystals of the salt deposited in the cup.

Fig. 4.



This copper vessel is then immersed in a vessel of glazed

porcelain *i*, containing a solution of the sulphate of zinc or the chloride of sodium (common salt). A hollow cylinder of zinc *h*, split down the side so as to be capable of being enlarged, or contracted at pleasure, is immersed in this solution surrounding the bladder. The poles are indicated by the conductors *p* and *n*, the positive proceeding from the copper, and the negative from the zinc.

M. Pouillet states that the action of this apparatus is sustained without sensible variation for entire days, provided the cup above the cone *d* is kept supplied with the salt, so as to maintain the solution in the saturated state.

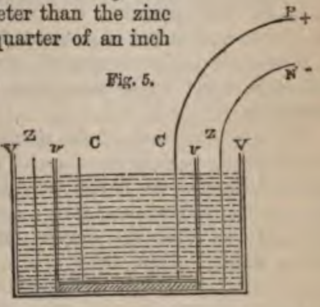
In the batteries used for the telegraphs on the French railways, the liquid in which the zinc cylinder is immersed is pure water, and this is found to answer in a very satisfactory manner.

The current flows from the copper cylinder and returns as usual to the zinc.

34. Grove's battery consists of two liquids, sulphuric and nitric acids, and two metals, zinc and platinum, arranged in the following manner:—

A hollow cylinder of zinc Z Z, fig. 5, open at both ends as already described, is placed in a vessel of glazed porcelain V V. Within this is placed a cylindrical vessel *v v*, of unglazed porcelain, a little less in diameter than the zinc Z Z, so that a space of about a quarter of an inch may separate their surfaces. In this vessel *v v*, is inserted a cylinder C C of platinum, open at the ends, and a little less than *v v*, so that their surfaces may be about a quarter of an inch asunder. Dilute sulphuric acid is then poured into the vessel V V, and concentrated nitric acid into *v v*; P proceeding from the platinum will then be the positive, and N proceeding from the zinc the negative pole.

Fig. 5.



Bunsen contrived a battery which has taken his name, and which, while it retains all the efficiency of Grove's, can be constructed at much less expense, the platinum element being replaced by the cheaper material of charcoal.

In the vessel *v v* is inserted, instead of a hollow cylinder of platinum, a solid cylindrical rod of charcoal, made from the residuum taken from the retorts of gas-works. A strong porous mass is produced by *repeatedly* baking the pulverised coke, to *which the required form is easily* imparted. Dilute sulphuric acid

is then poured into the vessel v v, and concentrated nitric acid into *v v*. The electric fluid issues from a wire connected with the charcoal, and returns by one connected with the zinc.

Messrs. Deleuil and Son, of Paris, have fabricated batteries on this principle with great success. I have one at present in use consisting of fifty pairs of zinc and carbon cylinders, the zinc being 2½ inches diameter, and 8 inches high, which performs very satisfactorily.

The chief advantage of Daniel's system is that from which it takes its name, its *constancy*. Its power, however, in its most efficient state, is greatly inferior to that of the carbon or platinum systems of Bunsen and Grove. A serious practical inconvenience, however, attends all batteries in which concentrated nitric acid is used, owing to the diffusion of nitrous vapour, and the injury to which the parties working them are exposed by respiring it. In my own experiments with Bunsen's batteries the assistants have been often severely affected.

In the use of the platinum battery of Grove, the nuisance produced by the evolution of nitrous vapour is sometimes mitigated by enclosing the cells in a box, from the lid of which a tube proceeds which conducts these vapours out of the room.

In combinations of this kind, Dr. O'Shaugnessy substituted gold for platinum, and a mixture of two parts by weight of sulphuric acid to one of saltpetre for nitric acid.

The method of producing the electric fluid by the mutual action of magnets and bodies susceptible of magnetism will be described hereafter.

35. Although each of the simple combinations described above would produce an electric current, which, being transmitted upon a conducting wire, would be attended with effects sufficiently distinct to manifest its presence, such a current would be too feeble in its intensity to serve the purposes of a telegraphic line; and as no other simple voltaic combination yet discovered would give to a current the necessary intensity, the object has been attained by placing in connection a series of such combinations, in such a manner that the currents produced by each of them being transmitted in the same direction, on the same conducting wire, a current having an intensity due to such combination may be obtained.

Such a series of simple voltaic combinations, so united, is called a VOLTAIC BATTERY.

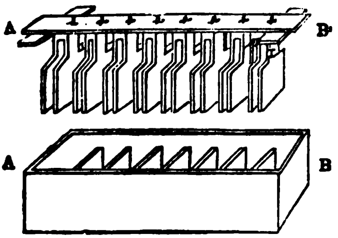
CABLE IN THE HOLD OF THE VESSEL

THE ELECTRIC TELEGRAPH.

CHAPTER II.

36. ONE of the most simple forms of voltaic battery is that represented in fig. 6, which consists of a glazed earthenware trough, divided by partitions into a series of parallel cells, and a series of zinc and copper plates, A′ B′, of shape and magnitude corresponding with the cells, attached to a wooden rod, each copper plate being connected at the top, under the wood, by a band of metal, with the zinc plate which immediately succeeds it in the series. For brevity, let us designate the first copper plate, C_1, the second C_2, the third, C_3, and so on, proceeding from A′ towards B′, and let the first zinc plate, which is connected with C_1 by a metal band, be called Z_2, the next, which is similarly connected with C_2, be called Z_3, and so on from A′ towards B′. Now, the intervals between the plates being so arranged as to correspond with the width of the cells, the series of plates may be let down into the cells so that a partition shall separate every pair of plates which are connected by a metal band. Thus, the first partition will pass between C_1 and Z_2, the second between C_2 and Z_3, the third between C_3 and Z_4, and so on. It appears, therefore, that the first cell proceeding from A towards B will contain only the copper plate C_1, the second will contain C_2 and Z_2, the third, C_3 and Z_3, and so on, the last cell at the extremity B of the series containing only the last zinc plate, which we shall call Z_n.

Fig. 6.



Now, it is evident that as the arrangement thus stands, the first and last cells of the series would differ from the intermediate ones, inasmuch as, while each of the latter contains a pair of plates, each of the former contains only a single plate, the first copper C_1 and the last zinc Z_n. To complete the arrangement, therefore, it will be necessary to place a zinc plate, which we shall call Z_1, in the first cell to the left of C_1, and so as not to be in contact with it, and in like manner a copper plate, which we shall call C_n, in the last cell B to the right of Z_n, and so as not to be in contact with it. Let wires be soldered to the upper edges of these terminal plates Z_1 and C_n, and let them be carried to any desired distances, but finally connected with plates, or any other masses of metal, buried in the ground at *n′* and *p′*, fig. 7.

These dispositions being made, let us suppose the cells to be filled with a weak acid solution, such as has been already described, *but so that* the liquid in one cell may not overflow into the next.

A current of electricity will now be established along the wire passing as indicated by the arrows, from the last copper plate at P,

Fig. 7.

to the earth at p', and returning by n' to the first zinc plate z_1, at N.

This current is produced by the combined voltaic action of all the pairs of plates contained in the cells of the trough.

37. The current produced by the combination z_1 c_1, in the first cell, will flow from the plate c_1 by the band of metal to the plate z_2, in the second cell. It will follow this course because of the conducting power of the metals, and the insulating power of the wood and earthenware, which prevents its escape. From the plate z_2 it will pass through the acidulated water to the plate c_2, for although this water has not a conducting power equal to that of metal, it has nevertheless sufficient to continue the current to c_2. From c_2 it will pass by the band of metal to z_3, and from that through the liquid in the third cell to c_3, and from that by the metal to z_3, and so on until it arrives at the last plate c_n of the series, from which it will pass, by the conducting wire, from P to p'.

It is evident, therefore, that the current produced by the voltaic combination in the first cell must pass successively through the plates and liquid in all the cells before it can arrive at P.

In the same manner it may be shown that the current produced in the second cell containing z_2 and c_2 must pass through all the succeeding cells before it can reach P, and so of all the others.

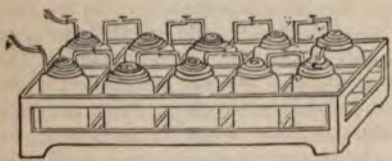
38. Now, if the metals and liquid were perfect conductors, each of these currents would arrive at P with undiminished force, and then the current upon the wire P p' would be as many times more intense than a current produced by a single voltaic combination as there are cells. But this is not so. The metals copper and zinc, though good conductors, are not perfect ones, and the acidulated water is a very imperfect one. The consequence is, that the currents severally produced in each of the cells, suffer a considerable loss of force before they arrive at the conducting wire Pp'; and mathematical formulæ, based on theoretical principles and practical data, have been contrived to express in each case the effects of th

diminution of force due to the imperfect conducting power, or the *resistance*, as it has been called, of the elements of the battery.

Without going into the reasoning upon which these investigations are founded, it will be sufficient for our present object to state, that in all cases, a current of greater or less force is transmitted to the terminal plate of the series from each of the cells, no matter how numerous they may be, and in some cases batteries have been constructed and brought into operation, in scientific researches, which consisted of as many as two thousand pairs of plates.

39. To simplify the explanation, as well as because the form described is very generally used for telegraphic purposes, we have here selected the plate battery to illustrate the general principle upon which all voltaic combinations are founded. In fig. 8 is represented the disposition of the cylinders in a battery formed on the principles of Daniel or Grove, where the metallic connection of each copper or charcoal element of one pair, with the zinc element of the succeeding pair, is represented by a rectangular metallic bar or wire.

Fig. 8.



40. Each combination of two metals, or of one metal and charcoal, which enters into the composition of a battery, is usually called a PAIR, and sometimes an ELEMENT. Thus, a battery is said to consist of so many PAIRS, or so many ELEMENTS.

The end of the battery from which the current issues is called its POSITIVE POLE, and that to which it returns is called its NEGATIVE POLE. Thus, in the batteries explained above, P is the positive, and N the negative pole.

Since in the most usual elements, zinc and copper, the current issues from the last copper plate, and returns to the first zinc plate, the positive pole is sometimes called the COPPER POLE, and the negative the ZINC POLE.

41. The voltaic battery is sometimes called the VOLTAIC PILE. This term had its origin from the forms given to the first voltaic combination by its illustrious inventor.

The first pile constructed by Volta was formed as follows:—A disc of zinc was laid upon a plate of glass. Upon it was laid an equal disc of cloth or pasteboard, soaked in acidulated water. Upon this was laid an equal disc of copper. Upon the copper were laid, in *the same order*, three discs of zinc, wet cloth, and copper, and the

same superposition of the same combinations of zinc, cloth, and copper, was continued until the pile was completed. The highest disc (of copper) was then the positive, and the lowest disc (of zinc) the negative pole, according to the principles already explained.

It was usual to keep the discs in their places by confining them between rods of glass.

Such a pile, with conducting wires connected with its poles, is represented in fig. 9.

Fig. 9.

42. As the batteries used on telegraphic lines are liable to frequent removal from place to place while charged with the acidulated water, or other exciting liquid, it has been found desirable to contrive means to prevent such liquid from being spilled, or thrown from cell to cell. This has been perfectly accomplished by the simple expedient of filling the cells with silicious sand, which is kept saturated with the exciting liquid so long as the battery is in operation.

43. It is often necessary, in telegraphic operations, to vary the intensity of the current. This is accomplished, within certain limits, without changing the battery, in the following manner:—

If it be desired to give the full force of the battery to the current, the wires are attached to the terminal plates, so that the entire battery is between them. But if any less intensity is desired, the wires, or one of them, is attached to intermediate plates, so that they shall include between them a part only of the battery. The part included between them is alone active in producing the current, all the elements which are outside the wires being passive. The battery, in effect, is converted into one of fewer elements.

Provisions are made, which will be explained hereafter, by which the operator can, by a touch of the hand, thus vary the force of the battery.

44. The batteries generally used for the English telegraphs are those described in (36). They are usually charged with sand, wetted with water mixed with sulphuric acid, in the proportion of about one part of strong acid to fifteen of water. A more intense current could be produced by using a stronger solution, but it is found preferable to augment its intensity by increasing the number of plates in the battery. The dimensions

of the plates are generally four to five inches wide, and three to four inches deep. The thickness of the zinc plates is something less than a quarter of an inch. The cells are filled with sand to within an inch of the top, and the parts of the plates above the sand are varnished as a protection against corrosion, and to keep them clean. In general, the troughs are made either of glazed gutta percha or some compact wood, such as oak, or teak, made water-tight by cement or marine glue. When the trough is wood the partitions of the cells are slate, the width of each cell being one inch and a quarter to one inch and a half. The troughs contain, some twenty-four, and some twelve cells.

Batteries of this sort, consisting of twenty-four cells, give a current of sufficient force for a line of wire of 15 miles. For 50 miles, 48 cells, and for 75 miles, three troughs of 24 cells are required. Mr. Walker considers that these batteries give superfluous force, but that it is necessary to provide against the contingency of leakage by accidental defects of insulation.

45. The durability of these batteries is increased by amalgamating the zinc plates. This is effected by first washing them in acidulated water, and then immersing them in a bath of mercury for one or two minutes. The mercury will combine with the zinc and form a superficial coating of the amalgam of zinc. When they are worn by use, they may be restored, by scouring them, and submitting them to the same process, and this may be continued until the zinc become too thin to hold together.

Mr. Walker states that new batteries, when carefully put together, will, with care, do duty for six or eight months, when the work is not very heavy; and by washing the sand out with a flow of water, and refilling them, they have frequently remained on duty ten or twelve months, or even more, without having been sent in for re-amalgamation.*

46. Having explained, generally, the manner in which the electric current is produced and maintained, I shall now proceed to explain the various expedients by which it is conducted from station to station, along the telegraphic line, and by which injurious waste by leakage or drainage is prevented or diminished.

The conducting wires used for telegraphic lines are of iron, usually the sixth of an inch in diameter. On all European lines they are submitted to a process called galvanisation, being passed through a bath of liquid zinc, by which they become coated with that metal. This zinc surface being easily oxydable, is soon, by the action of air and moisture, converted into the oxyde of zinc, which, being insoluble by water, remains upon the wire, and protects the iron from all corrosion.

* El. Tel. Manip., p. 8.

When a great length of wire is to be stretched between two distant points without intermediate support, steel wire is often preferred to iron, in consequence of its greater strength and tenacity.

Copper being a better conductor of electricity than iron, as well as being less susceptible of oxydation, would on these accounts be more eligible for telegraphic purposes. Its higher price, and the possibility of compensation for the inferior conducting power of iron, by using greater battery power, has rendered it preferable to use that metal.

47. Mr. Highton, the inventor of some important improvements in telegraphic apparatus, affirms that, when galvanised iron wires pass through large towns where great quantities of coal are burnt, the sulphureous acid gas resulting from such combustion acting upon the oxyde of zinc which coats the conducting wire, converts it into a sulphate of zinc, which being soluble in water, is immediately dissolved by rain, leaving the iron unprotected. The wire consequently soon rusts, and is corroded. Mr. Highton says, that in some cases he has found his telegraph wires reduced by this cause to the thinness of a common sewing needle in less than two years.

The wires used on the American lines are of iron, similar to the European, but are not galvanised. They soon become coated with their own oxyde. A pair of galvanised wires have been placed between New York and Boston, and I have been informed by Mr. Shaffner, the secretary of the American Telegraph Confederation, that at certain times during the winter, it has been found that they were unable to work the telegraph with these wires, while its operation with the wires not galvanised, was uninterrupted. Mr. Shaffner also states that several anomalous circumstances have been manifested upon some extensive lines of wire erected on the vast prairies of Missouri. Thus, in the months of July and August, it is found that the telegraph cannot be worked from two to six in the afternoon, being the hottest hours of the day. These circumstances are ascribed to some unexplained atmospheric effects.

48. The manner in which the conducting wires are carried from station to station is well known. Every railway traveller is familiar with the lines of wire extended along the side of the railways, which, when numerous, have been not unaptly compared to the series of lines on which the notes of music are written, and which are the metallic wires on which invisible messages are flying continually with a speed that surpasses imagination. These are suspended on posts, erected at intervals of about sixty yards, being at the rate of thirty to a mile. They therefore supply incidentally a convenient means by which a passenger can ascertain the speed

of the train in which he travels. If he count the number of telegraph posts which pass his eye in two minutes, that number will express in miles per hour the speed of the train.

49. Since the current of electricity which flows along the wire has always a tendency to pass by the shortest route possible to the ground, it is evident that the supports of the wires upon these posts ought to possess, in the highest attainable degree, the property of insulation; for even though the entire stream of electrical fluid might not make its escape at any one support, yet if a little escaped at one and a little at another, the current would, in a long line, be soon so drained that what would remain would be insufficient to produce those effects on which the efficiency of the telegraph depends. Great precautions have therefore been taken, and much scientific ingenuity has been expended in contriving supports which shall possess, in the highest attainable degree, the property of insulation.

50. To each of these posts or poles are attached as many tubes or rollers, or other forms of support, in porcelain or glass, as there are wires to be supported. Each wire passes through a tube, or is supported on a roller; and the material of the tubes or rollers being among the most perfect of the class of non-conducting substances, the escape of the electricity at the points of contact is impeded.

Notwithstanding various precautions of this kind, a considerable escape of electricity still takes place in wet weather. The coat of moisture which collects on the wire, its support, and the post, being a conductor, carries away more or less of the fluid. Consequently, more powerful batteries are necessary to give effect to the telegraph in wet than in dry weather.

In England, and on the Continent, the material hitherto used for the supports of the wires is principally a sort of earthen or stone ware. In the United States it is generally glass.

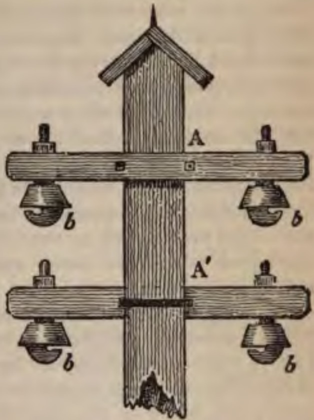
51. The forms of these insulating supports are various. Tubes, rings, collars, and double cones, are severally used. The material used most commonly in England, a sort of brown stoneware, has the advantage, besides being a good insulator, of throwing off wet, as water falls from a duck's wing, leaving the surface dry. A pitcher of this ware, plunged in water, scarcely retains any moisture upon it.

52. The posts vary generally from 15 to 30 feet in height, the lowest wire being about ten feet above the ground, except in cases where greater height is required to allow vehicles to pass under it, as when the wires cross a common road, or pass from one side of the railway to the other. The poles are about 6 inches square at the top, and increase to 8 inches at the bottom. In some cases they are impregnated with certain chemical solutions, to preserve them from rotting, and are generally painted, the parts

which are in the ground being charred and tarred. The manner of treatment, however, varies in different countries.

53. In figs. 10 and 11 are represented different forms of supports used in England. To cross-pieces of wood, A A′, bolted upon the post (fig. 10), are attached balls, *b*, of stoneware, as described above, in which grooves or slits are formed to receive and support the wires. These supports are protected from rain and from the deposition of dew by hoods of zinc-coated iron placed over them. Glass being so much better an insulator, balls of that material are recently being substituted for the stoneware.

Fig. 10.



Another form of support, sheltered by a sort of sloping roof, is represented in fig. 11. On the front of the post is a wooden arm to which a series of stone-ware rings are

Fig. 11.

attached, through which the wires pass. These rings have the form of two truncated cones placed with their larger bases in contact.

It is usual, where the wires are numerous, as on some of the lines near London, to attach these supports both to the front and

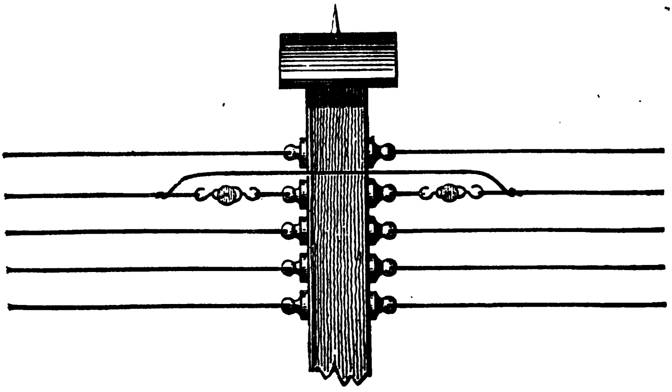
back of the post. So many as thirteen of these supports may be seen upon some of the posts of the North-Western line near London. The wires supported on some of these are continued to Liverpool and Manchester, and some even to Glasgow.

54. If the same wire were carried over a succession of supports for a certain distance, they would after a certain time become slack and hang in curves between post and post. This would be attended with great inconvenience and confusion, inasmuch as one wire—especially when agitated by wind—would come in contact with another, so that the currents running along them would pass from one to another, and the proper signals conveyed by such currents would no longer reach their destination.

To prevent this, apparatus for tightening the wire are on all such lines provided at convenient distances, such as half-a-mile, upon posts which are thence called *winding posts*. These posts are of larger dimensions than the ordinary posts. A grooved drum, on which the wire is wound, is attached to them by a bolt, which passes through the post, but clear of the wood. Upon this bolt is fixed a ratchet wheel by which the drum may be turned in one direction, so as to coil the wire upon it, with a catch which prevents its recoil in the other direction, and therefore maintains the tension of the wire. The bolt is kept from contact with the post by passing through a stoneware collar.

The current passes through the winder and the bolt, these being metallic, but in case of any interruption arising from the

Fig. 12.



oxydation of their surfaces a supplemental piece of conducting wire is provided, which connects the main wires at points taken above and below the winding post, as represented in fig. 12.

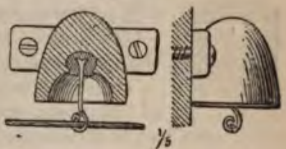
55. In France the posts are from twenty to thirty feet high, placed at distances varying from sixty to seventy yards asunder, and sunk to a depth of from three to seven feet in the ground. They are impregnated with sulphate of copper to preserve them from rotting by damp.

The conducting wire rests in an iron hook, which is fastened by sulphur into the highest part of the cavity of an inverted bell, formed of porcelain, from which two ears project, which are screwed to the post.

A section of this apparatus is given in fig. 13, and a side view in fig. 14, the figures being one-fifth of the actual magnitude.

The winding posts are placed at distances of a kilometre (six-tenths of a mile). The apparatus used for tightening the wire consists of two drums or rollers, each carrying on its axis a ratchet wheel with a catch. These drums are mounted on iron forks formed at the ends of an iron bar, which is passed through an opening in a porcelain support, and secured in its position by pins, the porcelain support being attached to the post by screws passing through ears projecting from it.

Figs. 13, 14.



A front view of this winding apparatus is given fig. 15; a side view of the porcelain support showing the opening through which the iron bar is passed, and the screws by which it is attached to the post, is given in fig. 16. These figures are one-fifth of the real magnitude of the apparatus.

Fig. 15.

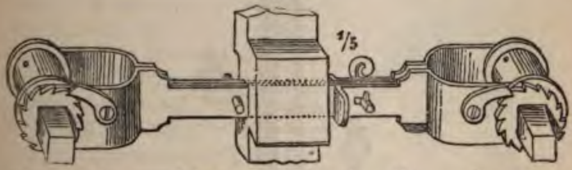
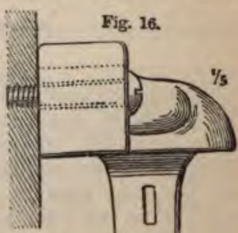


Fig. 16.



The conducting wires used in France are similar to those used on the English lines.

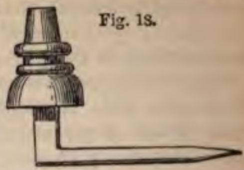
56. The insulating supports of the wires used on the American lines are very various in form.

The supports upon the principal Morse lines consist of a glass knob,

fig. 17, upon which two projecting rings are raised in the groove between which the wire is wrapped. This glass knob is attached to an iron shank as represented in fig. 18, which is driven into the post.

Fig. 17.

Fig. 18.

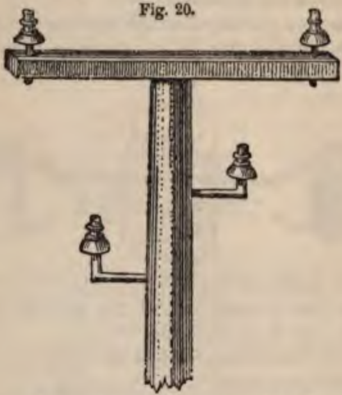


Another form of support used on these lines is represented in fig. 19, which consists of two rectangular blocks of glass, in each of which is a semi-cylindrical groove corresponding with the thickness of the conducting wire, so that the wire being laid in the groove of one of them, and the other being laid upon it, will be completely enclosed within the block of glass produced by their union. These blocks of glass are surrounded and protected by a larger block of wood, as represented in the figure, where the white part represents the glass, and the shaded part the wood.

Fig. 19.

The supports are sometimes attached to the sides of the posts, and sometimes placed upon an horizontal cross bar, as represented in fig. 20.

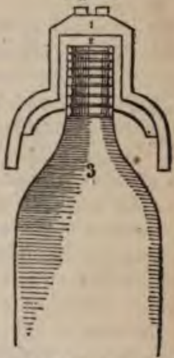
Fig. 20.



The supports used in House's lines consist of a glass cap about five inches in length and four inches in diameter, having a coarse screw-like surface cut inside and out. This glass cap (2) fig. 21 is screwed and cemented into a bell-shaped iron cap (1) from three to four pounds, in weight, projecting an inch below the lower edge of the glass, protecting it from being broken; this is fitted with much care to the top of

the pole (3), and is covered with paint or varnish. The conducting wire is fastened to the top of the cap by projecting iron points, and the whole of the iron cap is thus in the circuit, as the wire is of iron and not insulated. To prevent the deposit of moisture, the glass is covered by a varnish of gum-lac dissolved in alcohol, and the ring-like form of the glass is to cause any moisture to be carried to the edge and there drop off.*

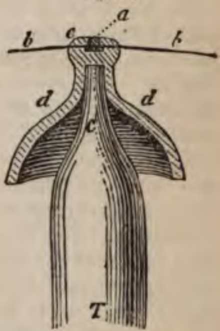
Fig. 21.



The wires on the American lines are not usually galvanised.

57. One of the forms of insulating support used on the German lines is represented in fig. 22, and consists of an insulating cap placed on the tapering end of a post T. The post terminates in a point *c*, an inch and a half in length and about six lines in diameter; this pole is covered with a porcelain cap *d d*, a sort of reversed cup; on its summit *e*, there is a hole inlaid with lead, in which the conducting wire *b b* enters; this insulator is then covered with a roof.

Fig. 22.



58. It may be asked what prevents the escape of the electric fluid from the surface of the wire between post and post? In general when wires are used on a smaller scale for the transmission of electric currents, the escape of the fluid is prevented by wrapping them with silk or cotton thread, which thus forms a non-conducting cover upon them, but on the scale on which they are used on telegraphic lines the expense of this, independently of the difficulty of protecting such covering from destruction by weather, would render it inadmissible.

59. The atmosphere, when dry, is a good non-conductor; but this quality is impaired when it is moist. In ordinary weather, however, the air being a sufficiently good non-conductor, a metallic wire will, without any other insulating envelope except the air itself, conduct the stream of electricity to the necessary distances. It is true that a coated wire, such as we have

* Turnbull on the Electric Telegraph, p. 176. Philadelphia, 1853.

described, would be subject to less waste of the electric fluid *en route;* but it is more economical to provide batteries sufficiently powerful to bear this waste, than to cover such extensive lengths of wire with any envelope.

60. Atmospheric electricity having been found to be occasionally attracted to the wires, and to pass along them, so as to disturb the indications of the telegraphic instruments, and sometimes even to be attended with no inconsiderable danger to those employed in working the apparatus; various expedients have been contrived for removing the inconvenience and averting the danger. The current produced by this atmospheric electricity is often so intense as to render some of the finer wires used in certain parts of the apparatus at the stations, red hot, and sometimes even to fuse them. It also produces very injurious effects by demagnetising the needles, or imparting permanent magnetism to certain bars of iron included in the apparatus, which thus become unfit for use.

61. One of the expedients used for the prevention of these inconvenient and injurious effects is to place common lightning conductors on the posts. The points of these are shown upon the posts in figs. 10, 11, and 12.

62. Mr. Walker of the South Eastern Company and M. Breguet of Paris, have each invented an instrument for the better protection of telegraphic stations from atmospheric electric discharges. Both these contrivances have been found in practice to be efficacious, and though differing altogether in form they are similar in principle. In both, a much finer wire than any which lies in the regular route of the current is interposed between the line wire and the station, so that an intense and dangerous atmospheric current must first pass this fine wire before reaching the station. Now it is the property of such a current to raise the temperature of the conductor over which it passes to a higher and higher point in proportion to the resistance which such conductor offers to its passage. But the resistance offered by the wire is greater in the same proportion as its section is smaller. The safety wire interposed in these contrivances is, therefore, of such thinness that it must be fused by a current of dangerous intensity. The wire being thus destroyed all electric communication with the station is cut off, and the extent of the inconvenience is the temporary suspension of the business of the line until the breach has been repaired.

Expedients are used on the American lines to divert the atmospheric electricity from the wires, consisting merely of a number of fine points projecting from a piece of metal connected with the earth by a rod of metal. These points are presented

a metal plate, or other surface, attached to the line wire at the place where it enters the station. It is found that these points attract the atmospheric electricity, which passes to the ground by the conductor connected with them, but do not attract the electricity of the battery current.

63. The wires extended from post to post are continued in passing the successive stations of the line. The expedients by which the current is turned aside from the main wire, and made to pass through the telegraphic office of the station, differ more or less in their details on different lines and in different countries, but are founded on the same general principles. It will therefore be sufficient here to describe one of those commonly used on the British lines.

The conducting wire of the main line in passing the station is cut and the ends jointed by a shackle, as represented in fig. 12, in the case of a winding post. This shackle breaking the metallic continuity would stop the course of the current. A wire is attached to the line wire below the shackle so as to receive the current which the latter would stop, and is carried on insulating supports into the telegraphic office and put in connection with the telegraphic instrument. Another wire connected with the other side of the instrument receives the current on leaving it, and being carried back on insulating supports to the line wire, is attached to the latter above the shackle, and so brings back the current which continues its progress along the line wire.

64. Although the mode of carrying the conducting wires at a certain elevation on supports above the ground has been the most general mode of construction adopted on telegraphic lines, it has been found in certain localities subject to difficulties and inconvenience, and some projectors have considered that in all cases it would be more advisable to carry the conducting wires underground.

This underground system has been adopted in the streets of London, and of some other large towns. The English and Irish Magnetic Telegraph Company have adopted it on a great extent of their lines, which overspread the country. The European Submarine Telegraph Company has also adopted it on the line between London and Dover, which follows the course of the old Dover mail-coach road by Gravesend, Rochester and Canterbury.

65. The methods adopted for the preservation and insulation of these underground wires are various.

The wires proceeding from the central telegraph station in London were wrapped with cotton thread, and coated with a mixture of tar, resin, and grease. This coating forms a perfect insulator. Nine of these wires are then packed in a half-inch leaden pipe, and four or five such pipes are packed in an iron pipe about three inches in diameter. These iron pipes are then laid

under the foot pavements, along the sides of the streets, and are thus conducted to the terminal stations of the various railways, where they are united to the lines of wire supported on posts along the sides of the railways, already described.

More recently, however, the wires deposited in the underground pipes are insulated altogether by means of a coating and envelope of gutta-percha.

The Electric Telegraph Company has at present (August, 1854) no less than fifteen miles of this underground piping laid along the streets of London, containing three hundred and fifty miles of gutta-percha covered conducting wire.

Since the paragraph (54) was put in type, we learn that the same company has abandoned the winding posts, and that the wires are tightened on every common post by means of a fine wire or strong tarred yarn, so that the expansion and consequent slackening of the conducting wire can only take place between post and post.

66. Provisions, called *testing posts*, are made at intervals of a quarter of a mile along the streets, by which any failure or accidental irregularity in the buried wires can be ascertained, and the place of such defect always known within a quarter of a mile.

Fig. 34.—LAYING THE CABLE FROM THE DECK OF THE SHIP.

THE ELECTRIC TELEGRAPH.

CHAPTER III.

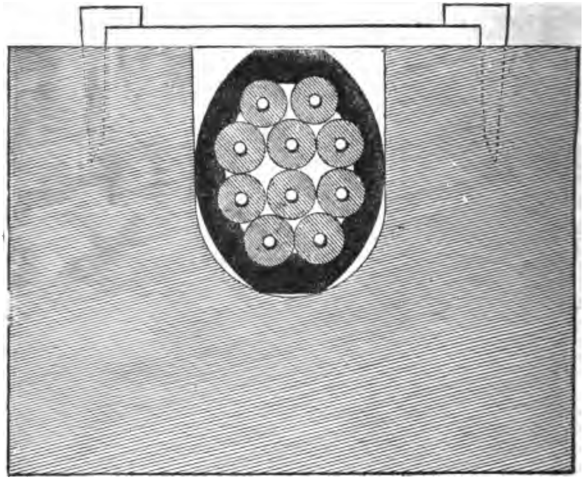
67. Wires of Magneto-electric Telegraph Company.—68. Mr. Bright's method of detecting faulty points.—69. Such failure of insulation rare.—70. Underground method recently abandoned in Prussia.—71. Underground wires of the European and Submarine Company.—72. Imperfect insulation in tunnels.—73. Mr. Walker's method of remedying this.—74. Overground system adopted through the streets of cities in France, and in the United States.—75. Telegraphic lines need not follow railways.—76. Do not in America nor in certain parts of Europe.—77. Submarine cables.—78. Cable connecting Dover and Calais.—79. Failure of first attempt—Improved structure.—80. Table of submarine cables and their dimensions.—81. Dimensions and structure of the Dover and Calais cable.—82. Holyhead and Howth cable.—83. First attempt to lay cable between Portpatrick and Donaghadee—its failure.—84. Dover and Ostend.—85. Portpatrick and Donaghadee.—86. Orfordness and the Hague.

67. The wires of the Magnetic Telegraph Company are laid and protected in the following manner.

Ten conducting wires are enveloped in a covering of gutta-percha, so as to be completely separated one from another. Thus prepared they are deposited in a square creosoted wooden trough measuring three inches in the side, so that nearly a square inch of its cross section is allowed for each of the wires. This trough is deposited on the bottom of a trench cut two feet deep along the side of the common coach road. A galvanised iron lid, of about an eighth of an inch thick, is then fastened on by clamps or small tenter hooks, and the trench filled in.

A section of the trough in its actual size is given in fig. 23.

Fig. 23.—Galvanised Iron Lid, No. 14, Birmingham Wire Gauge.



Creosoted Deal Troughing.

The method of laying the wires in the streets adopted by this company is a little different. In this case iron pipes are laid, but they are split longitudinally. The under halves are laid down in the trench, and the gutta-percha covered wires being deposited, the upper halves of the pipes are laid on and secured in their places, by means of screws through flanges left outside for the purpose.

To deposit the rope of gutta-percha-covered wires in the trough it is first coiled upon a large drum, which being rolled along slowly and uniformly over the trench, the rope of wires is payed off easily and evenly into its bed.

So well has this method of laying the wires succeeded that in Liverpool the entire distance along the streets from Tithe Barn

Railway station to the Telegraph Company's offices in Exchange Street, East, was laid in eleven hours; and in Manchester the line of streets from the Salford Railway station to Ducie Street, Exchange, was laid in twenty-two hours. This was the entire time occupied in opening the trenches, laying down the telegraph wires, refilling the trenches and relaying the pavement.

68. One of the objections against the underground system of conducting wires, was, that while they offered no certain guarantee against the accidental occurrence of faulty points where their insulation might be rendered imperfect, and where, therefore, the current would escape to the earth, they rendered the detection of such faulty points extremely difficult. To ascertain their position required a tedious process of trial to be made from one testing post to another, over an indefinite extent of the line.

A remedy for this serious inconvenience, and a ready and certain method of ascertaining the exact place of such points of fault without leaving the chief, or other station at which the agent may happen to be, has been invented and patented by the Messrs. Bright of the Magnetic Telegraph Company.

Instruments called Galvanometers, which will be more fully described hereafter, are constructed, by which the relative intensity of electric currents is measured by their effect in deflecting a magnetic needle from its position of rest. The currents which most deflect the needle have the greatest intensity, and currents which equally deflect it have equal intensities.

The intensity of a current diminishes as the length of the conducting wire—measured from the pole of the battery to the point where it enters the earth—is augmented. Thus, if this length be increased from twenty miles to forty miles, the intensity of the current will be decreased one half.

The intensity of the current is also decreased by decreasing the thickness of the conducting wire. Thus the intensity, when transmitted on a very thin wire, will be much less than when transmitted on a thick wire of equal length; but the thick wire may be so much longer than the thin that its length will compensate for its thickness, and the intensity of the current transmitted upon it may be equal to that transmitted on the shorter and thinner wire.

The method of Messrs. Bright is founded upon this property of currents. A fine wire wrapped with silk or cotton so as to insulate it and prevent the lateral escape of the current, is rolled upon a bobbin like a spool of cotton used for needle-work. A considerable length of fine wire is thus comprised in a very small bulk.

The wire on such a bobbin being connected by one end with the *wire conducting a current,* and by the other end with the earth,

will transmit the current with a certain intensity depending on its length, its thickness, and, in fine, on the conducting power of the metal of which it is made.

Now let us suppose that a certain length of the wire of the telegraphic line be taken, which will transmit a current of the same intensity. A galvanometer placed in each current will then be equally deflected. But if the length of the line wire be less or greater than the exact equivalent length, the galvanometer will be more or less deflected by it than it is by the bobbin wire, according as its length is less or greater.

It is, therefore, always possible by trial to ascertain the length of line wire, which will give the current the same intensity as that which it has upon any proposed bobbin wire.

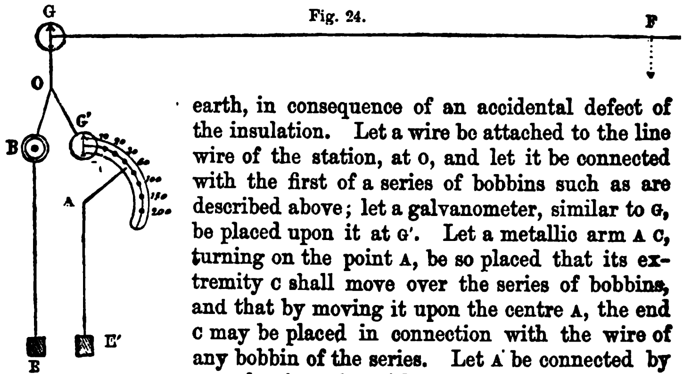
Bobbins may therefore be evidently made carrying greater or less lengths of wire, upon which the current will have the same intensity as it has upon various lengths of line wire.

Suppose then a series of bobbins provided, which in this sense represent various lengths of line wire from 100 feet to 300 miles, and let means be provided of placing them in metallic connection in convenient cases.

Such an apparatus is that by which the Messrs. Bright detect the points of fault.

Let B be the station battery, G a galvanometer upon the line wire, F the point of fault at which the current escapes to the

Fig. 24.



earth, in consequence of an accidental defect of the insulation. Let a wire be attached to the line wire of the station, at O, and let it be connected with the first of a series of bobbins such as are described above; let a galvanometer, similar to G, be placed upon it at G'. Let a metallic arm A C, turning on the point A, be so placed that its extremity C shall move over the series of bobbins, and that by moving it upon the centre A, the end C may be placed in connection with the wire of any bobbin of the series. Let A be connected by a conducting wire with the earth at E', the negative pole of the battery B being connected with the earth at E.

The apparatus being thus arranged, let us suppose that the wire A C is placed in connection with the first bobbin, representing 10 miles of the line wire, and that the distance G F of the point of fault is 145 miles. In that case the battery current will be

divided at O, between the two wires O G and O G′, but the chief part will flow by the shortest and easiest route, and the galvanometer G′ will be very much, and G very little, deflected. This will show that F must be very much more than 10 miles from the station. The arm A C will then be turned successively from bobbin to bobbin. When directed to the second bobbin, the current on O G′ will have the same intensity as if it flowed on 20 miles of line wire, when turned to the third the same as if it flowed on 30 miles of line wire, and so on. The needle of G′ will, therefore, continue to be more deflected than that of G, although the difference will be less and less, as the number of bobbins brought into the circuit is increased. When the bobbins included represent 140 miles, G′ will be a little more, and when they represent 150 miles it will be a little less deflected than G, from which it will be inferred that the point of fault lies between the 140th and the 150th mile from the station. A closer approximation may then be made by the introduction of shorter bobbins, and this process may be continued until the place of the fault has been discovered with all the accuracy necessary for practical purposes.

69. It appears nevertheless, that in the practical working of the telegraphic lines, occasions for the application of these expedients are of extremely rare occurrence. During the four winter months of November, December, January, and February 1853-54, distances of 300 miles of underground wire, without any break of circuit, have been in constant operation under the Magnetic Telegraphic Company, and notwithstanding an unusual prevalence of unfavourable weather, with frequent and continued snow-storms, no stoppage whatever has taken place.

70. The Prussian underground lines of wire have been attended, however, with occasional failures, which have produced some public inconvenience. This circumstance has been ascribed to the faulty method of laying the wires. The gutta-percha enveloping them was mixed with sulphur, a process called *Vulcanisation.* Upon being deposited in the ground the sulphur was soon abstracted, leaving the gutta-percha brittle and porous.

71. The underground line of the European and Submarine Company, from London to Dover, is laid down in nearly the same manner as that of the Magnetic Company. There are six conducting copper wires encased in gutta-percha. To detect the more easily the place of any accidental breach of continuity, a box is placed at the end of each mile, in which a few yards of the continuous line of wire are coiled, so that in case of any accidental interruption occurring to the flow of the current, the particular mile in which that interruption exists can always be ascertained by putting the *coils at the* end of each successive mile in

connection with a portable battery. The current will fail at the particular mile within which the fault has taken place.

72. In passing through tunnels the overground wires have been subject to great inconvenience, owing to the quantity of water percolating through the roof, constantly falling on the wires and their supports, and thus injuring their insulation. It has been found that from this cause the current transmitted along one wire has been subject to leakages, a part of it passing by the moisture which surrounds the supports to an adjacent wire, so that being thus divided, part either returns to the station from which it has been transmitted, or goes on to a station for which it is not intended.

73. This inconvenience would be removed by adopting for tunnels the under-ground system. Mr. Walker, to whom great experience in the practical business of electric telegraphy, and considerable scientific knowledge must give much authority on such a subject, has adopted apparently with very favourable results a method of covering the wires, which pass through tunnels, with a coating of gutta-percha. The conducting wire thus treated is copper wire No. 16. The gum being well cleaned and macerated by steam, is put upon the wire by means of grooved rollers. The diameter of the covered wire is a quarter of an inch. Mr. Walker states that in all the wet tunnels under his superintendence he has substituted this gutta-percha-covered wire for the common line wire, and has thus "accomplished telegraphic feats which could not have been attempted on the old plan."

74. In France and in the United States the wires, even in the cities and towns, are conducted on rollers at an elevation, as on other parts of the lines. In Paris, for example, the telegraphic wires proceeding from the several railway stations are carried round the external boulevards and along the quays, the rollers being attached either to posts or to the walls of houses or buildings, and are thus carried to the central station at the Ministry of the Interior.

75. In Europe, the telegraphic wires have until very lately invariably followed the course of railways; and this circumstance has led some to conclude that, but for the railways, the electric telegraph would be an unprofitable project.

76. This is however a mistake. Independently of the case of the Magnetic Telegraph Company already mentioned, the wires in the United States, where a much greater extent of electric telegraph has been erected and brought into operation than in Europe, do not follow the course of the railways. They are conducted, generally, along the sides of the common coach-roads, and sometimes even through tracts of country where no roads have been made.

It has been contended in Europe that the wires would not be safe unless placed within the railway fences. The reply to this is, that they are found to be safe in the United States, where there is a much less efficient police, even in the neighbourhood of towns, and in most places no police at all. It may be observed, that the same apprehensions of the destructive propensities of the people have been advanced upon first proposing most of the great improvements which have signalised the present age. Thus, when railways were projected, it was objected that mischievous individuals would be continually tearing up the rails, and throwing obstructions on the road, which would render travelling so dangerous that the system would become impracticable.

When gas-lighting was proposed, it was objected that evil-disposed persons would be constantly cutting or breaking the pipes, and thus throwing whole towns into darkness.

Experience, nevertheless, has proved these apprehensions groundless; and certainly the result of the operations on the electric telegraph in the United States goes to establish the total inutility of confining the course of the wires to railways. Those who have been practically conversant with the system both in Europe and in America, go further, and even maintain that the telegraph is subject to less inconvenience, that accidental defects are more easily made good, and that an efficient superintendence is more easily insured on common roads, according to the American system, than on railways.

These reasons, combined with the urgent necessity of extending the Electric Telegraph to places where railways have neither been constructed nor contemplated, have led to the general departure of the telegraphic wires from the lines of railway in various parts of the continent. In France, particularly, almost all the recently-constructed telegraphic network is spread over districts not intersected by railways, and even where railways prevail, the wires are often, by preference, carried along the common road.

77. When channels, straits, arms of the sea, or rivers of great width intervene between the successive points of a telegraphic line, the conducting wires are deposited upon the bottom of the water, protected from the effects of mechanical and chemical action by various ingenious expedients. A considerable number of such subaqueous conductors have been fabricated for telegraphic lines in various countries, and others are in progress or contemplated. Before June 1854, wire ropes had been made for the lines between Dover and Calais, Dover and Ostend, Dublin and Holyhead, Donaghadee and Portpatrick, England and Holland, the *Zuyder Zee, the Great* Belt (Denmark), the Mississippi, New *Brunswick and Prince* Edward's Island, and Piedmont and Corsica.

78. The earliest attempt to transmit a voltaic current under water for telegraphic purposes, is attributed to Dr. O'Shaughnessy, who is so well known for his successful exertions to establish the electric telegraph in India. He succeeded in 1839 in depositing an insulated conducting wire, attached to a chain cable, in the river Hoogly, by which the electric current was transmitted from one bank of that river to the other.

The first important project of this kind which was executed in Europe, was the connection of the coasts of England and France by the submarine cable, deposited in the bed of the channel between Dover and Calais. A concession being obtained from the French government on certain conditions, a single conducting wire, invested with a thick coating of gutta-percha, was sunk by means of leaden weights across the channel, and the extremities being put into connection with telegraphic instruments, messages were transmitted from coast to coast. One of the conditions of the French concession being that this should be effected before September, 1850, this object was attained, but nothing more; for the action of the waves near the shore constantly rubbing the rope against the rocky bottom, soon wore off the insulating envelope and rendered the cable useless.

79. It is right to state that the projectors themselves did not expect from this first trial permanent success, and regarded it merely as the experimental test of the practicability of the enterprise. It was, therefore, immediately resolved to resort to means for the effectual protection of the conducting wires from the effects of all the vicissitudes to which they would be exposed. With this view, Messrs. Newall and Co., the eminent wire-rope makers of Gateshead, were charged with the difficult and unprecedented task of discovering expedients, by which a cable of gutta-percha containing the conducting wires could be invested with an armour of iron, at the same time so strong as to resist the action of the forces to which it would be exposed, and yet not too ponderous or too rigid to allow of being deposited in the bed of the channel. The result was the invention of the form of submarine cable, which has since been successfully adopted upon the various lines of international electric communication which will be presently described.

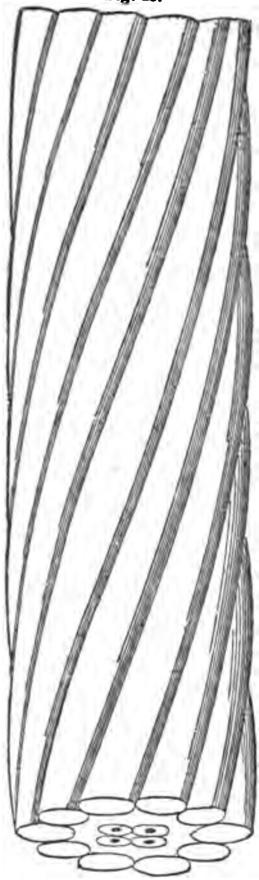
The conducting wires inclosed in these cables are usually copper wires, having a diameter of the sixteenth of an inch. Each wire is first separately covered with two coatings of gutta-percha. Each successive coating increases the thickness by a certain fraction of an inch. The object of laying on this succession of coats of the gum, is to guard against accidental *defects which* might render the insulation imperfect. If such a

defect happened to exist at any point of the first coat it would be covered by the second, the chances against a defect occurring at the same point of both coatings amounting to an impossibility.

80. The conducting wire thus invested, or so many of them as it is intended to deposit, are then twisted together, and surrounded with a mass of spun yarn, soaked with grease and tar, so as to form a compact rope. Around this rope are then twisted a number of stout iron wires, sometimes coated on the surface with zinc, or as it has been called, galvanised. The cable is then complete, and is fabricated in one continued length sufficient to extend from shore to shore, or from bank to bank. Perspective side views of the several cables, and transverse sections of them in their full size, are given in the figures indicated in the first column of the following table, the number of conducting wires insulated by the gutta-percha and included within the cables, the number of surrounding iron wires, the total length from coast to coast, and the weight of the cables per mile respectively being indicated in the other columns.

	Fig.	No. of copper wires.	No. of iron wires.	Total length—Miles.	Weight per mile—Tons
Dover and Calais	25, 26	4	10	25	7
Holyhead and Howth	27, 28	1	12	70	1
Dover and Ostend	31, 32	6	12	70	7
Portpatrick and Donaghadee (Magnetic Comp.)	35, 36	6	12	25	7
Orfordness and the Hague . . .	37, 38	1	10	135	2
Across the Great Belt (Denmark) . .	41, 42	3	9	16	5
Across the Mississippi	45, 46	1	8	2	2
Across the Zuyder Zee	43, 44	6	10	5	7¼
Newfoundland & Prince Edward's Island	39, 40	1	9	150	1¾
Portpatrick and Donaghadee (British Comp.)	35, 36	6	12	27	7
Spezzia and Corsica	35, 36	6	12	110	8
Corsica and Sardinia	35, 36	6	12		8

Fig. 25.



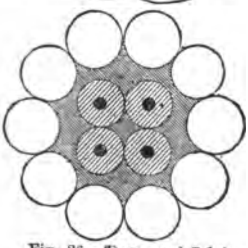


Fig. 26.—Dover and Calais.

81. In the Dover and Calais cable, which was the first fabricated and laid, each of the four copper wires are surrounded by gutta-percha, which in fig. 26 is indicated by the light shading round the black central spot, representing the section of the copper wire. The four wires thus prepared were then enveloped in the general mass of prepared spun yarn, represented by the darker shading. The ten galvanised iron wires were then twisted around the whole, so as to form a complete and close armour. The external form and appearance of this heliacal coating is represented in fig. 25.

This cable which was completed by Messrs. Newall and Co., in three weeks, measured originally 24 miles in length. Owing to the manner in which it was laid down this was found insufficient to extend from coast to coast, although the direct distance is only 21 miles. It was therefore found necessary to manufacture an additional mile of cable, which being spliced on to the part laid, the whole was completed, and the electric communication between Dover and Calais definitively established on the 17th October, 1851.

The cost of the cable itself was 9000*l.*, being at the rate of 360*l.* per mile. The total cost for cable and stations at Dover and Calais was 15,000*l.*

82. The next submarine cable laid down was that which connected Holyhead on the Welsh with Howth on the Irish coast. While several companies which had been formed for the purpose, were occupied in raising the capital necessary for this project, they were surprised by the

announcement that the project was already on the point of being realised by Messrs. Newall and Co., on their own account.

The distance between the points to be connected being 60 miles, the cable was made with a length of 10 addition miles, to meet contingencies. In this cable, which enclosed only one conducting wire, the external wires enclosing the insulating rope were made thicker at the parts near the shores than for that which lies in deep water, the former being subject to much greater disturbing forces. A side view of the part immersed in deep water is given in fig. 27, and a cross-section in fig. 28. A side view of the shore ends is given in fig. 29, and a cross-section in fig. 30, all being in their full size.

Fig. 27.

Fig. 28.
Holyhead and Howth.
Deep sea part.

Fig. 29.

Fig. 30.
Holyhead and Howth.
Shore ends.

The gutta-percha rope was fabricated by the Gutta Percha Company in the City-road, London, from whence it was sent to Gateshead, where it received the iron wire envelope at the works of Messrs. Newall and Co., in the short space of four weeks. Loaded on twenty waggons, it was next sent by railway across England to Maryport, where it was embarked on board the "Britannia," and transported to Holyhead. On the morning of the 1st June, 1852, one of its extremities being established at Holyhead, it was laid in the bed of the channel. This was done as follows:—The cable was very carefully coiled in the hold of the steamer; one end was then passed several times round a brake-wheel, and was conveyed on shore, when it was attached to a telegraph instrument. The other or lower end of the cable was attached to another instrument in the cabin of the steamer, so that any message passing from instrument to instrument, was conveyed through the

cable in the hold, and round the brake-wheel as the cable passed off in the process of submersion. The shore end having been made fast securely, the steamer was put in motion, and a certain strain was put on the cable by means of the brake-wheel, so that it was laid straight on the ground, or bottom of the sea.

The cable is seen as it rises from the hold in the foreground, (fig. 34, p. 145,) guided between rollers to the drum, and it again appears in the back ground, as it passes over the stern. A counter and indicator was applied to the shaft of the drum by which the length of cable which at any moment had been delivered off into the sea was shown.

The wind and tides have the effect of drawing the vessel out of her course, so that the quantity of cable expended must always be greater than the distance between the two points in a straight line. In the case of the Holyhead and Howth cable, the quantity expended was 64 miles. The depth of water is 70 fathoms, being more than twice that of Dover.

The entire process of laying it down was completed in 18 hours. In another hour the cable was brought ashore, and put in connection with the telegraphic wires between Howth and Dublin, and immediately afterwards London and Dublin were connected by means of instantaneous communication.

This cable was lighter considerably than that between Dover and Calais, its weight being a little less than one ton per mile, and consequently its total weight did not exceed 80 tons, while the Dover and Calais cable weighing 7 tons per mile, its total weight was 180 tons.

From some cause, which could not be ascertained, this cable, after being worked for three days, became imperfect. It was supposed to have been caught by the anchor of some vessel, for on being taken up lately, it was found broken near Howth, and the gutta-percha and copper wire stretched in an extraordinary manner.

83. On the 9th October, 1851, Messrs. Newall and Co. attempted to lay a cable across the narrowest part of the Irish channel, between Port Patrick and Donaghadee. This cable contained six conducting wires, similar to fig. 43. The distance across is the same as between Dover and Calais, viz., 21 miles, and 25 miles of cable were placed on board the "Britannia" steamer. The process of submersion was carried on until 16 miles had been successfully laid down, when a sudden gale came on, which rendered it impossible to steer the vessel in the proper course, and Mr. Newall was reluctantly compelled to cut the cable, when within 7 miles of the Irish coast, and having 9 miles of cable remaining on board.

The whole of this 16 miles of cable has been recovered in

June, 1854, after being nearly two years submerged. This proved a most arduous undertaking. The depth of the water in this part of the Irish channel is 150 fathoms, or 900 feet, and from this depth the cable was dragged by means of a powerful apparatus worked by a steam engine placed on the deck of a steamer. The operation occupied four days, for from the great force of the tide, which runs at the rate of 6 miles an hour, it was found impossible to work except at the times of high and low water. The cable was also imbedded in sand, so that the strain required to drag it up was occasionally very great.

The recovery of this cable has so far solved the question of the durability of submarine telegraphs. It was found nearly as sound as when laid down. There was a slight corrosion in certain parts which appeared to have been imbedded in decaying sea weed—the parts imbedded in sand were quite sound, and on other parts, which appeared to have rested on a hard bottom, there were a few zoophytes. The cable on being tested was found as perfect in insulation as when laid down.

84. The next great enterprise of this kind, of which the accomplishment must render for ever memorable the age we have the good fortune to live in, was the deposition in the bed of the Channel of a like cable connecting the coasts of England and Belgium, measuring SEVENTY MILES IN ONE UNBROKEN LENGTH! This colossal rope of metal and gutta-percha was also constructed at the works of Messrs. Newall and Co.

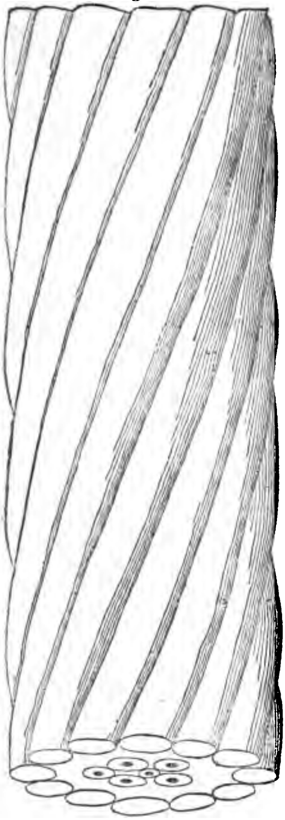
The probable extension of these extraordinary media of social, commercial, and political communication between countries separated by arms of the sea, may be conceived, when it is stated that during the winter of 1852-53 Messrs. Newall and Co. executed under contracts not less than 450 miles of such cable.

The cable laid between Dover and Calais includes, as already stated, four conducting wires. That between Dover and Ostend contains six wires insulated by the double covering of gutta-percha, manufactured, under Mr. S. Statham's directions, by the Gutta Percha Company. The gutta-percha laid into a rope is served with prepared spun-yarn, and covered with twelve thick iron wires, of a united strength equal to a strain of 40 to 50 tons —more than the proof strain of the chain cable of a first rate man-of-war.

A side view and section of this cable in its natural size are given in figs. 31 and 32 (page 158).

The Belgian cable weighed 7 tons per mile, so that its total weight was about 500 tons. Its cost was 33,000*l*. It took 100 days to make it, and 70 hours to coil it into the vessel from which it was let down into the sea, and 18 hours to submerge it.

Fig. 31.



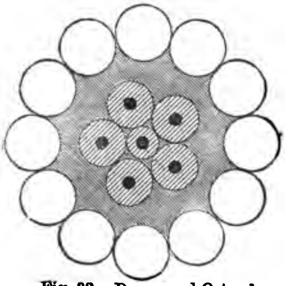


Fig. 32.—Dover and Ostend.

The form in which it was coiled in the hold of the vessel is represented in fig. 33 (p. 129).*

On the morning of the Wednesday, the 4th May 1853, the vessel called the "William Hutt," Capt. Palmer, freighted with the cable, being anchored off Dover, near St. Margaret's, South Foreland, the process of laying the cable was commenced. This vessel was attended and aided by H.M.S. "Lizard," Capt. Rickets, R.N., and H.M.S. "Vivid," Capt. Smithett. Capt. Washington, R.N., was appointed, on the part of the Admiralty, to mark out the line and direct the expedition.

At dawn of day about 200 yards of the cable were given out from the "Hutt," and were extended by small boats to the shore, where the extremity was deposited in a cave at the foot of the cliff. There telegraphic instruments were provided by means of which, through the cable itself, a constant communication with the vessel was maintained during the arduous process, corresponding telegraphic instruments being placed on board the "Hutt."

At 6 o'clock, the process of laying commenced, the "Hutt" being taken in tow by the steam tug "Lord Warden."

The manner in which the cable was "payed out," as the vessel proceeded in its course, is represented in fig. 34 (p. 145), the cable as it came up from the hold, being

* This illustration, as well as that of the deposition of the cable, have been taken from the *Illustrated London News* of the 14th of May, 1853, by the consent of the publishers of that journal.

passed several times round a large brake-wheel, by means of which the cable was kept from going out too fast, and its motion maintained so as to be equal to the progress of the vessel. Men are represented in the figure applying the brake to the wheel.

On arriving off Middlekerke, on the Belgian coast, a boat sent from shore took from 500 to 700 yards of the cable on board, for the purpose of landing it. The boats of the British vessels taking her in tow, the end of the cable was safely landed, and deposited in a guard-house of the Custom House; where the telegraphic instruments brought in the "Hutt" being erected, and the communications made, the following despatch was transmitted direct to London:—

Union of Belgium and England, twenty minutes before one, p.m. 6*th May* 1853.

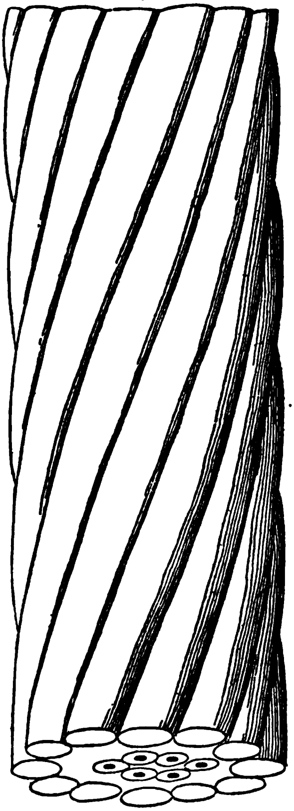
85. The next submarine cable laid, was that of the Magnetic Telegraph Company, connecting Donaghadee with Port Patrick, also manufactured by Messrs. Newall and Co.

This cable, which contains six conducting wires, is represented in its proper size in figs. 35, 36, and corresponds in weight and form to the Belgian cable. But in the details of its construction and composition, some improvements were introduced. This rope was manufactured in 24 days, and cost about 13,000*l*.

The cable laid down by the British Telegraph Company between the same points, is precisely similar to this.

86. It is proposed to connect Orfordness, on the Suffolk coast, with the Hague. by seven separate submarine cables, each containing a

Fig. 35.



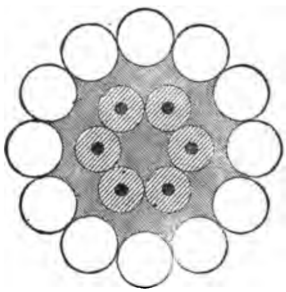
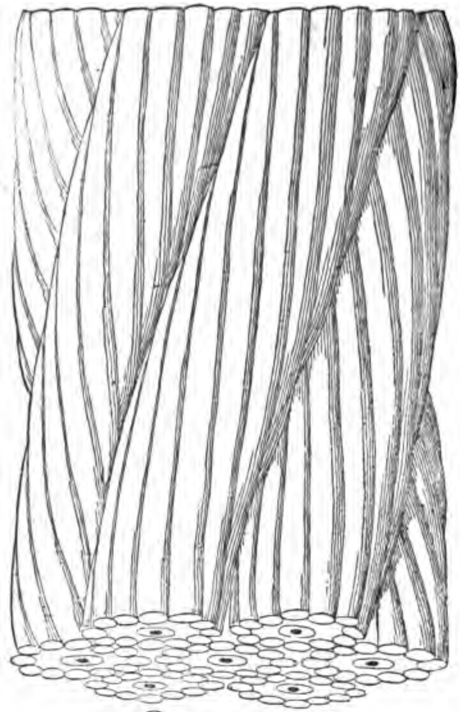


Fig. 36.—Donaghadee and Portpatrick, (Magnetic Telegraph Company.)

Fig. 37.



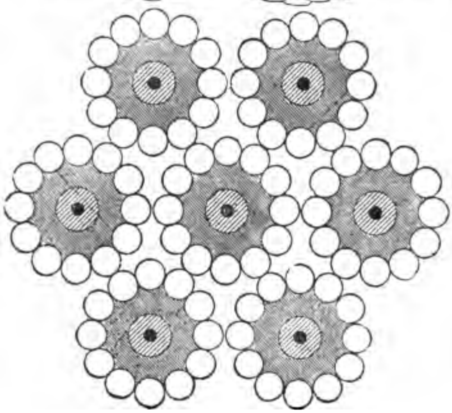


Fig. 38.—Orfordness and the Hague.

single wire. Near the shore on each side these will be brought together and twisted into a single great cable, as represented in figs. 37, 38.

Of these, only three have been laid down. The distance from Orfordness to the Hague being 120 miles, the cables were made 135 miles in length. They were laid down separately at a little distance one from another. At 3½ miles from the shore they were brought together. When the telegraphic business increases the other four will be deposited.

Fig. 66.—THE SINGLE NEEDLE TELEGRAPH.

THE ELECTRIC TELEGRAPH.

CHAPTER IV.

87.—Cable between Spezzia and Corsica.—88. Other cables, European and American.—89. Objections brought by scientific authorities to the submarine cables—Answers to these by practical men.—90. Example of a cable uninjured by the action of the sea.—91. Precautions necessary in laying the cable.—92. Accident in laying the Calais cable.—93. Imperfection attributed to the Belgian cable.—94. Transatlantic Ocean Telegraph.—95. Underground wires between the Strand and Lothbury.—96. Effect of the inductive action of underground or submarine wires.—97. Possible influence of this on telegraphic operations.—98. Examples of overground wires extended to great distances without intermediate support—between Turin and Genoa.—99. Telegraphic lines in India.—100. Difficulties arising from atmospheric electricity—height and distance of posts—mode of laying underground wires—extent of line erected to April 1854.—101. Intensity of current decreases as the length of wire increases.—102. Also *increases with the thickness* of the wire.—103. And *with the number of elements* in the battery.—104. Result of Pouillet's *experiments on the intensity* of current.—105. Intensity produced by

87. It is proposed to connect Europe with the islands of the Mediterranean and the African continent, by extending the wires which already run continuously to Genoa from the United Kingdom and the Northern States of Europe to Spezzia, and from that point to lay a submarine cable to Corsica, another between Corsica and Sardinia, and another between Sardinia and Bona. The latter place would be connected with Alexandria by underground wires extending along the coast.

It is even regarded as within the scope of probability that Alexandria may be put in electrical connection with Bombay; and as the latter place is already connected by a telegraphic line with Calcutta, a continuous line of communication between London and Calcutta would thus be established.

The distances between Spezzia and Bona on the coast of Algeria are:—

	Miles.
Spezzia to Corsica (submarine)	76
Across Corsica (underground)	128
Corsica to Sardinia by the straits of Bonifacio (submarine) .	7
Across Sardinia (underground)	203
Sardinia to Bona, on the coast of Algeria, (submarine) about	125
	539

There would thus be 208 miles of submarine cable in three lengths of 76, 7, and 125 miles, and 331 miles of overland wires necessary to connect the southern coast of Europe with the northern coast of Africa.

This is the proposed plan, and the cables from Spezzia to Corsica, and from Corsica to Sardinia are already laid and in operation; but it will be obvious on inspecting the map that the object would be attainable with a less extent of submarine cable by continuing the overland line to Piombino, in the Grand Duchy of Tuscany, connecting that place with the Island of Elba by a submarine cable of 8 or 10 miles, and connecting the westernmost point of Elba with Bastia, in Corsica, by another cable of 35 to 40 miles. This method would have the further advantage of including in the line several important places on the Italian coast; such as, Carrara, Massa, Lucca, Pisa, and Leghorn.

A preference has been given to the course above described in consideration of the benefit conferred upon the company by the concession and guarantee granted by the government of Sardinia, which would not have been given had the other course been followed.

The cable now deposited contains six conducting wires, and is in all respects similar to that represented in figs. 35, 36.

Figs. 39, 40.

P. Edward's Island and N. Brunswick.

88. The short submarine cable laid down between Prince Edward's Island, and the coast of Nova Scotia (figs. 39, 40), is intended as part of a more extended submarine line connecting Newfoundland with Canada. The other sections would make up a total length of 140 miles; but the project is reported to be arrested for the present by the refusal of the House of Assembly of Nova Scotia to grant a charter to the company to cross that province.

The Danish submarine cable (figs. 41, 42), is carried across the Great Belt from Nyborg to Korsoe the nearest point of the opposite coast of Zealand.

The cable laid across the Zuyder Zee is shown in its proper size in figs. 43, 44 (p. 164).

Subaqueous cables have been laid across several of the American rivers. The difficulties supposed to attend the deposition and preservation of these conductors appeared to telegraphic engineers and projectors so formidable, that the wires were at first carried *across the rivers be-*tween the summits of

Fig. 41.

Fig. 42.—Great Belt.

Fig. 43.

Fig. 44.—Zuyder Zee

lofty masts erected on their banks. This method, however, was found to be attended with such effects as to render the maintenance of the wire impracticable. The masts were blown down by the violent storms and tornadoes incidental to the climate, and were not unfrequently destroyed by lightning.

The project of depositing the conducting wires in the bottom of the river was then resorted to, and has been carried into effect in several cases. The Ohio is crossed at Paducah by a cable containing one conducting wire, of which the following description is given in the American journals.

"It is composed of a large iron wire, covered with three coatings of *gutta percha*, making a cord of about five-eighths of an inch in diameter.

"To protect this from wear, and for security of insulation, there are three coverings of strong *Osnaburg*, saturated with an elastic composition of *non-electrics;* and around this are eighteen large iron wires, drawn as tight as the wire will bear, and the whole is then spirally lashed together with another large wire, passing around at every $\frac{3}{4}$ of an inch. The whole forms a cable of near two inches in diameter."

This cable is 4200 feet in length, being the longest yet laid down in the United States. It was constructed by Messrs. Shaffner and Sleeth.

Mr. Shaffner has also constructed and deposited subaqueous cables in the following places:—

Across the Tennessee river, four miles above Paducah, near its

junction with the Ohio. Length, 2200 feet; same construction; deposited in 1851.

Across the Mississippi, at Cape Girondeau, in the State of Missouri. Length 3700 feet; deposited in 1853.

Across the Merimmac river, where it falls into the Mississippi, twenty miles below St. Louis. Length, 1600 feet; deposited in 1853.

All these are similar to the Paducah cable.

Across the Mississippi at St. Louis, three cables for different lines, each enclosed by 14 lateral external wires. Length, 3500 feet. Deposited in 1852-3.

Across the Ohio at Maysville, Kentucky, a cable containing two conducting wires, enclosed by 28 lateral external wires, constructed like the former. Length, 2700 feet. Deposited in 1853.

Across the Ohio at Henderson, Kentucky. Length, 3200 feet. Deposited in 1854.

Cables constructed by Messrs. Newall and Co. have also been deposited in the following places:—

Across the Mississippi at New Orleans, containing one conducting wire. Length, 3000 feet. Deposited in 1853. Shown in figs. 45, 46.

Across the Hudson, 10 miles above New York; similar construction. Length, 3600 feet. Deposited in 1854.

Across the Straits of Northumberland, at the mouth of the St. Lawrence; similar construction. Length, 10 miles. Deposited in 1853.

At certain places on the great western rivers serious difficulties have been and are still encountered in the preservation of these subaqueous conductors. At St. Louis on the Mississippi, and at Paducah on the Ohio, for example, several cables have been successively swept away by floods. Large trees carried down the stream are, one after another, stopped by being caught in the cable, and the number thus accumulated becomes at length so great that the force of the current, acting upon them, breaks it.

Another frequent cause of destruction to these cables in the *Western Continent* is the attraction *they offer to atmospheric* electricity. They are *frequently destroyed* by lightning. Mr. Shaffner

Fig. 45.

Fig 46.—Mississipp[i]

tells me that he has sometimes found a longitudinal incision measuring ten feet in length, made in the gutta-percha, by the lightning, and cut as clean as if it had been done with a razor. At other times he has found the gutta-percha swelled, rough and porous, and sometimes pierced with countless numbers of openings like pinholes.

These appearances are supposed by Mr. Newall to arise from imperfection in the covering of the wire. The slit, he thinks, is caused, by air getting in behind the arm, which holds the mandril through which the copper wire passes before leaving the cylinder, and the porous covering arises from air mixed with the gutta-percha. Mr. Newall has ascertained that a wet hair, or a hole of equal size is sufficient to destroy the insulation of the wire.

89. Some eminent scientific authorities express doubts as to the durability of the submarine cables. In the case of the Dover and Calais cable it has been observed that the bottom of the channel at that part of the strait is proved by the soundings to be subject to undulations, so considerable that the summits of some of its elevated points rise to such a height that the water which covers them is not deep enough to secure them from the effects of the tumultuous agitation of the surface in violent storms. It is here well to remind the reader that the agitation of the ocean, which seems so awful in great tempests, has been found to extend to a very limited depth, below which the waters are in a state of the most profound repose. The objection we now advert to is, therefore, founded upon the supposition that the crests of some of the elevations upon which the submarine cable rests are so elevated as to be within that limit of depth, and it is feared that such being the case, the violence of the water in great tempests may so move the cable against the ground on which it is deposited with a motion to and fro, as to wear away by frequent friction its metallic armour, and thus expose the conducting wires within it to the contact of the water, and destroy their insulation.

But it has been most satisfactorily proved by a part of the experimental wire which was laid down between Dover and Calais, in 1850, and which was picked up two years afterwards in as perfect a state as when laid down, that the action of the waves does not affect the bottom of the Channel there. The greatest depth is 30 fathoms, and the bottom shelves regularly from Dover to near Cape Grinez, where there is a ledge of rocks rising suddenly from the bottom.

It has been also feared that, notwithstanding the effect of the galvanisation of the surface of the surrounding wires, the corrosive action of the sea water may in time destroy them; and it has been *suggested* that some better expedient for protection against this

effect might be contrived upon the principle suggested by Davy, for the preservation of the copper sheathing of ships, by investing the cable at certain intervals with a thick coating or glove of zinc, which would increase the efficiency of the thinner coating of that metal given to it in the process of galvanisation.*

To this practical men who have had as much experience as is compatible with the recent date of these novel and extraordinary enterprises, reply that the results of their observations give no ground for apprehension of any injurious effects from tidal or tempestuous action, and that the fine iron used in the wire is not affected by sea water, as larger masses of coarser iron, such as anchors, are. They cite as proof of this, the slightly decayed state in which nails and small fire-arms have been found when recovered from vessels long sunk. They further state that the tar contained in the layer of hemp within the protecting wires acts as a preservative, whether the wires be galvanised or not. It has been found for example that, in the case of the submarine conductor between Donaghadee and Portpatrick, a perfect concrete of tar and sand has been already formed, upon which masses of shell-fish attach themselves at all parts that are not buried in sand, and it is apparent that in a few years a calcareous deposit will be formed around it, which will cement it to the bottom, and altogether intercept the action of the sea water.

90. In the deposition of submarine cables great care should be taken to select suitable points on the shore for beaching them. Sandy places are always to be sought. If this precaution be taken, it is affirmed that they are not subject to tidal action. A cable was partly laid by the Magnetic Telegraph Company in 1852 near Portpatrick (83), but abandoned in consequence of the vessel employed to deposit it being exposed in the process to a violent storm. The wire was left exposed upon the beach down to and beyond low water mark, and was in June, 1854, still in a perfect state, the galvanised iron wires, even to their zinc coating, being absolutely in the same state as when they were deposited.

91. It is contended by practical men that the great and only risk of failure in the submarine cables is from defects produced in the process of their deposition, or from original faults in the principle of their construction.

The greatest care is necessary in conducting the process of delivering out the cable into the sea, or "paying it out," as it is technically called. All sudden bending of the cable is to be especially avoided. "Kinks" or "hitches" are apt to occur in

* Pouillet, "Traité de Physique," vol. i. p. 799. Ed. 1853.

the process, by which the gutta percha covered wires within the cable are strained.

92. In laying the Calais cable it was found too short to extend to the opposite coast, and it became necessary to splice a supplementary piece to it. The joint thus formed afterwards failed, and it was found necessary to splice it anew, and to insert a fresh piece. Since this was done the cable appears to have continued in excellent order.

93. It is said that the Belgian cable has been subject to some imperfection arising from the position of the wires within the case. The sixth wire being in the axis of the cable, surrounded by the other five (see fig. 32), it was found that when the outer casing of the protecting wires was laid around it, the pressure on the centre wire rendered it imperfect, while the five surrounding it suffered to some extent.

Similar defects are said to exist in other cables constructed upon the same principle.

A hempen case well tarred in the centre is considered to form the best safeguard for the gutta percha covered wires in the process of making the cable, since it will yield to any compression itself without affecting injuriously the wire.

94. This notice of subaqueous telegraphy ought not to be concluded without some mention of the project for the deposition of an electric cable across the Atlantic, so as to put the Old World in instantaneous communication with the New. Such a scheme is regarded now pretty nearly as that for the electric connection of the British islands with each other and with the European continent was regarded some years ago. The sanguine consider the project practicable, and its speedy realisation probable. The more phlegmatic notice it only with ridicule. Men of science generally admit the possibility of the enterprise while men of finance more than doubt the possibility of a remunerative result.

The width of the Atlantic between the nearest points of British America and the west coast of Ireland is about sixteen hundred miles. Twelve cables, each as long as those which have been laid down between Orfordness and the Hague, would be sufficient to extend from coast to coast. That cable could be spliced to cable was practically proved between Calais and Dover, such a splice having been successfully made in the cable near the French coast.

Lieutenant Maury, of the United States, so well known for his hydrographical researches, caused a series of regular soundings to be made with the view of determining the form and condition of the bed of the ocean between the coasts of British America and

Ireland. He found that between Newfoundland, or the mouth of the river St. Lawrence, and the west coast of Ireland, the bottom consists of a plateau, which, as he says, "seems to have been placed there especially for the purpose of holding the wires of a submarine telegraph, and of keeping them out of harm's way. It is neither too deep nor too shallow; yet it is so deep, that the wires but once landed, will remain for ever beyond the reach of vessels, anchors, icebergs, and drifts of any kind; and so shallow that the wires may be readily lodged upon the bottom.

"The depth of this plateau is quite regular, gradually increasing from the shores of Newfoundland to the depth of 1500 to 2000 fathoms, as you approach the other side."*

Lieutenant Maury concludes that this line of deep sea soundings is quite decisive of the question, as to the practicability of a submarine telegraph between the two continents in so far as the bottom of the ocean is concerned. A cable laid across would pass to the north of the great banks, and would be deposited upon the plateau above described, where the waters of the ocean are proved to be "as still as those of a millpond."

This inference Lieutenant Maury deduces from the fact, that all the specimens of the bottom brought up have been found to consist of microscopic shells without the admixture of a single particle of gravel or sand. Had there been currents at those depths, these shells would have been thrown about and abraded, and mixed more or less with the *debris* of the natural bed of the ocean, such as ooze, sand, gravel, and other matter. "Consequently a telegraphic cable once laid there, there it would remain as completely beyond the reach of accident as if it were buried in air-tight cases."

Imperfectly informed persons have expressed an opinion that the cable would not sink below a certain depth, at which the increasing density of the sea water would render it bulk for bulk as heavy as the cable. The well known physical properties of water prove such a supposition to be groundless. Although not incompressible in an absolute sense, water is susceptible of compression, even at the greatest depths of the ocean, in so small a degree, that the cable must always greatly exceed it in specific weight.

Putting out of view the financial part of the question, there appears then to be no good reason for pronouncing the project to construct such a cable, and to deposit it in the bed of the ocean, impracticable in an absolute sense.

* *Report of Lieutenant* Maury to the Secretary of the U.S. Navy, *Feb. 22, 1854.*

It may be asked whether, if deposited, an electric current could be transmitted through it so as to produce telegraphic signals?

There can be only two reasons for doubting this—*first*, the length of the conducting wire, and, *secondly*, the inductive effects of the water upon the cable.

The intensity of the current transmitted by a battery of given power upon a wire, is in the direct ratio of the conducting power of the wire and the magnitude of its transverse section, and in the inverse ratio of its length. A length so great as 1500 or 1600 miles, would of course considerably attenuate the current.

But it will be recollected that, in the experiments described in Chap. I. par. 9, made by M. Leverrier and myself, messages were transmitted over a space of 1000 miles of wire without intermediate battery power, and with a terminal battery of very limited power. In that case 336 miles of the wire upon which the current was transmitted were iron, a very indifferent conductor, and the remaining 746 miles were copper wire of extremely small diameter. It is certain, therefore, that by reason of the inferior conducting power of the one part, and of the very small transverse section of the other part, this length of 1082 miles offered a much greater resistance to the transmission of the current than would 1600 miles of copper wire, such as is usually selected for submarine cables.

But independent of these considerations, nothing would be easier than to give the copper wire enclosed in the cable such a thickness, and to apply to it such batteries, as would ensure the transmission of a current of sufficient intensity.

The effects of the recoil currents produced by the inductive action of the water upon the cable, cannot be so certainly appreciated with our present knowledge and experience; but although the effects of these are sensible in the cases of the submarine and underground wires already laid down, they have not produced any obstruction to the efficient performance of the telegraphs, and the managers of the Magnetic Telegraph Company, which works well several hundred miles of wire partly subaqueous and partly underground, assure me that no inconvenience or obstruction whatever is found to arise from this cause. If no other objection were raised against the project of a Transatlantic cable save this, it may be safely pronounced that there would be nothing to be apprehended which the resources of science and art would not easily surmount.

It does not appear, therefore, that any part of the great problem of subatlantic telegraphy remains to be solved, except that which is involved in the financial view of the question. If it be undertaken as a commercial enterprise with a view to a

remunerative return, *will it pay?* Or, on the other hand, may it not be regarded as one of those vast international enterprises to which the influence and resources of states should be applied? These are questions which we have neither the space nor the vocation to discuss.

95. In 1852, the conducting wires which connect the Branch Telegraph Office, established in the Strand, opposite Hungerford Market, with the General Post-office, were laid down. In this case the conducting wires are galvanised brass instead of copper. They are as usual laid in iron tubes, and are carried along the kerb stones of the foot pavement of the Strand, Fleet-street, Ludgate-hill, and St. Paul's Church-yard to Cheapside, where they cross over to Foster-lane, and passing through the branch office in the hall of the General Post-office, are carried thence to the central telegraph station in Lothbury, at the rear of the Bank of England.

From this central office, at all hours by day and by night, despatches are transmitted to and received from every seaport and every considerable town in England, Scotland, and Wales; by the submarine wires, by Holyhead and Portpatrick, from all parts of Ireland, and by Dover, from all parts of the Continent of Europe where electric telegraphs have been constructed.

96. After the underground and submarine wires had been constructed and laid upon a considerable scale, the attention of Dr. Faraday was called by some of the parties engaged in their management to peculiar phenomena which had been manifested in the telegraphic operations made upon the lines thus laid. After experiments had been made upon a large scale with lines of subaqueous and subterranean wires, extending to distances varying from 100 to 1500 miles, it was found that the electricity supplied by the voltaic battery to the covered wire was in great quantity arrested there, by the attraction of electricity of an opposite kind evolved from the water or earth in which the wire is sunk; the attraction acting through the gutta percha covering exactly in the same manner as that in which the electricity developed by a common electric machine, and deposited on the inside metallic coating of an electric jar, acts through the glass upon the natural electricity of the external coating, or of the earth in connection with it. The two opposite electricities on the inside and outside of the coating of the wire by their mutual action neutralise each other, and under certain circumstances a person placing his hands in metallic connection with both sides of such coating, may ascertain the presence of a large charge of such neutralised fluid, by receiving the shock which it will give like that of a charged Leyden jar.

97. It is apprehended that this unforeseen phenomenon m[illegible]

interfere more or less with the practical working of all telegraphs having underground conducting wires; and I have been informed by the agents engaged in bureaux of the Paris telegraph, that they are sensible of its effects in all direct communications between that capital and London.

On the other hand the Magneto-Electric Telegraph Company, who at the present time (May, 1854), have nearly 900 miles of underground wire in operation, report that they sometimes pass their signals without any difficulty through 500 miles of underground wire without any break or delay in the circuit, and that they have in constant operation continuous underground lines connecting towns above 300 miles apart.

The only defect complained of in the underground wires is that which proceeds from accidental failures of complete insulation, produced by defects in the gutta percha or other coating which allow moisture to penetrate in wet weather and to reach the conducting wire, or it may arise from accidental fracture of the wire. In any such cases the flow of the current to its destination is interrupted, and the telegraph conveys no signal.

The use of underground wires, and the discovery of the phenomenon of inductive action above described, are too recent to justify any certain inference as to their effects on telegraphic operations. Time and enlarged experience alone can settle the questions which have been thus raised.

98. Although as a general rule the overground lines of telegraphic wire are sustained by supports at intervals of about sixty yards, many exceptional cases are presented in which they are extended between supports at much greater distances asunder. Every recent visitor to Paris may have observed the long lines of wire which are in several cases extended along the boulevards and across the river.

But the most surprising examples of long lines of wires without intermediate support, are presented on the telegraphic line passing north and south through Piedmont between Turin and Genoa. There, according to a report published in the "Piedmontese Gazette," in the course of the line passing through the district intersected by the chain of the Bochetta, the engineer, M. Bonelli, had the boldness to carry the wires from summit to summit across extensive valleys and ravines at immense heights above the level of the ground. In many cases the distance between these summits amounted to more than half a mile, and in some to nearly three-quarters of a mile. In passing through towns, this line is carried underground, emerging from which it is again stretched through the air from crest to crest of the Maritime Apennines, after which it finally sinks into the earth,

passing through Genoa under the streets and terminating in the Ducal palace.

It is stated that the insulation of the wires on this picturesque line has been so perfect, notwithstanding the adverse circumstances of its locality, that although it was constantly at work day and night during the first winter, no failure of transmission or extraordinary delay ever occurred.

99. Efforts have recently been made to extend the system of telegraphic intercommunication to India. Dr. O'Shaughnessy of the East India Company's medical department, in constructing an experimental line through a distance of 80 miles from Calcutta, used, instead of wires, iron rods, being the only obtainable materials. These were fastened together and supported on bamboos.

By experiments thus made, he found that the wires employed in Europe would be quite inadequate to the Indian telegraph. In England, where the lines are carried along railways, and where there are no living obstacles to contend with, the thin iron wire, called No. 8 gauge, answers its purpose well; but no sooner were the rods mounted on their bamboo supports in India than flocks of that largest of all birds, the adjutant, found the rods convenient perches, and groups of monkeys congregated upon them; showing clearly enough that the ordinary wire would be insufficient to bear the strains to which these telegraphic lines would be subjected. It was found also that not only must the wire be stronger, but that it must be more elevated, to allow loaded elephants, which march about regardless of roads or telegraphic lines, to pass underneath.

100. The telegraphic communication thus practically effected, is subjected to attacks to which the telegraphs in this country are but little exposed. Storms of lightning destroyed the galvanometer coils, and hurricanes laid prostrate the posts. Undaunted by the opposition of the elements, Dr. O'Shaughnessy contrived a lightning conductor for the instruments, and strengthened the supporting props.

Dr. O'Shaughnessy returned to England, and at Warley, near Brentwood, made arrangements for producing 3000 miles of thick galvanised wire, to be shipped for India; one of the earliest lines undertaken, to be from Calcutta to Bombay. One of the peculiar characteristics of the railway lines intended for India, as contrasted with the English lines, is the greater distance between the posts, which are higher and stronger than those generally used. The thick wire is raised to a height of fourteen feet, on posts nearly the eighth part of a mile apart. To obtain the necessary strength to bear the strain, the posts are fixed with screw

piles. To show the strength of the wires thus extended, a rope was, for experiment, hung to the centre of the wire of largest span, and a soldier climbed up it, the weight of his body producing but a slight curvature. The common deflection arising from the weight of a wire of a furlong span does not exceed eighteen inches.

Dr. O'Shaughnessy's plan of underground communication, when such a mode of laying down the wires is desirable, is very economical. The copper wires coated with gutta percha, instead of being inserted in iron tubes, are inlaid in wooden sleepers, well saturated with arsenic, to protect them from the white ants, and they are then laid in a trench about two feet deep. An underground system of two wires may thus be laid down for 35*l.* the mile.

The plan adopted for joining the lengths of the thick galvanised wire is to have the two ends turned, so as to link into one another, which are then introduced into a mould, like a bullet-mould, and an ingot of zinc being cast over them, they form a most substantial joint, and perfect metallic connection.*

It appears from reports received in May, 1854, that at that date a telegraphic line was in full operation from Calcutta to Agra, a distance of 800 miles, and it was then expected that the entire line to Bombay, a distance of 1500 miles, would soon be completed and put in operation.

This line is reported to have been completed and brought into operation since the preceding paragraphs were in type.

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101. To produce the effects, whatever these may be, by which the telegraphic messages are expressed, it is necessary that the electric current shall have a certain intensity. Now, the intensity of the current transmitted by a given voltaic battery along a given line of wire will decrease, other things being the same, in the same proportion as the length of the wire increases. Thus, if the wire be continued for ten miles, the current will have twice the intensity which it would have if the wire had been extended to a distance of twenty miles.

It is evident, therefore, that the wire may be continued to such a length that the current will no longer have sufficient intensity to produce at the station to which the despatch is transmitted those effects by which the language of the despatch is signified.

120. The intensity of the current transmitted by a given

* Year-Book of Facts, 1853, p. 150.

voltaic battery upon a wire of given length, will be increased in the same proportion as the area of the section of the wire is augmented. Thus if the diameter of the wire be doubled, the area of its section being increased in a fourfold proportion, the intensity of the current transmitted along the wire will be increased in the same ratio.

103. In fine, the intensity of the current may also be augmented by increasing the number of pairs of generating plates or cylinders composing the galvanic battery.

Since it has been found most convenient generally to use iron as the material for the conducting wires, it is of no practical importance to take into account the influence which the quality of the metal may produce upon the intensity of the current. It may be useful nevertheless to state that, other things being the same, the intensity of the current will be in the proportion of the conducting power of the metal of which the wire is formed, and that copper is the best conductor of the metals.

104. M. Pouillet found by well-conducted experiments, that the current supplied by a voltaic battery of ten pairs of plates, transmitted upon a copper wire, having a diameter of four-thousandths of an inch, and a length of six-tenths of a mile, was sufficiently intense for all the common telegraphic purposes. Now if we suppose that the wire instead of being four-thousandths of an inch in diameter, has a diameter of a quarter of an inch, its diameter being greater in the ratio of 62½ to 1, its section will be greater in the ratio of nearly 4000 to 1, and it will consequently carry a current of equal intensity over a length of wire 4000 times greater, that is, over 2400 miles of wire.

105. But in practice it is needless to push the powers of transmission to any such extreme limits. To reinforce and maintain the intensity of the current, it is only necessary to establish at convenient intervals along the line of wires intermediate batteries, by which fresh supplies of the electric fluid shall be produced, and this may in all cases be easily accomplished, the intermediate telegraphic stations being at distances, one from another, much less than the limit which would injuriously impair the intensity of the current.

106. Having thus explained the means by which an electric current can be conducted from any one place upon the earth's surface to any other, no matter what be the distance between them, and how all the necessary or desired intensity may be imparted to it, we shall now proceed to explain the expedients by which such a current may enable a person at one place to convey *instantaneously to another* place, no matter how distant, *signs serving the purpose of* written language.

It may be shortly stated that the production of such signals depends on the power of the agent transmitting the current to transmit, suspend, intermit, divert and reverse it at pleasure. These changes in the state of the current take place for all practical purposes simultaneously upon all parts of the conducting wire to whatever distance that wire may extend, for although strictly speaking there is an interval, depending on the time which the current takes to pass from one point to another, that interval cannot in any case exceed a small fraction of a second.

107. Although there is some discordance in the results of experiments made to determine the velocity of the current, they all agree in proving it to be prodigious. It varies according to the conducting power of the metal of which the wire is composed, but is not dependent on the thickness of the wire. On copper wire, its velocity, according to Professor Wheatstone's experiments, is 288000 miles; and according to those of MM. Fizeau and Gonelle, 112680 miles per second. On the iron wire used for telegraphic purposes, its velocity is 62000 miles per second, according to Fizeau and Gonelle; 28500 according to Professor Mitchell, of Cincinnati; and about 16000 according to Professor Walker of the United States.

108. It is evident therefore that the interval which must elapse between the production of any change in the state of the current at one telegraphic station, and the production of the same change at any other however distant, cannot exceed a very minute portion of a second, and since the transmission of signals depends exclusively on the production of such changes, it follows that such transmission must be practically instantaneous.

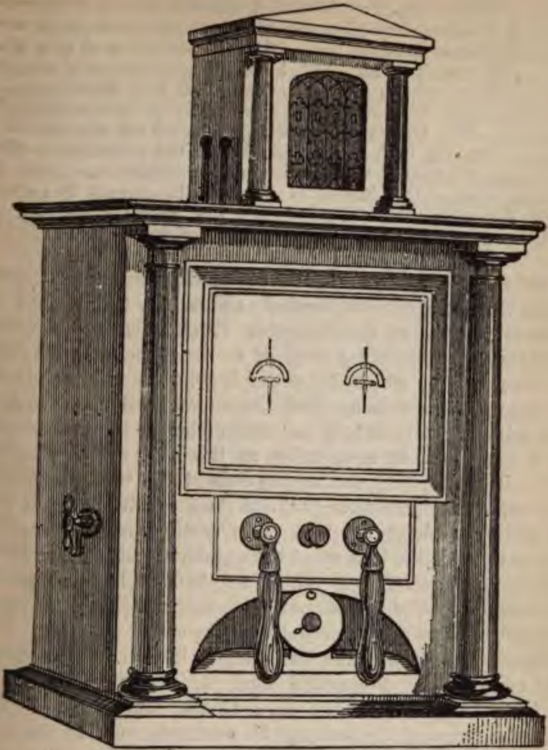


Fig. 68.—THE DOUBLE NEEDLE TELEGRAPH.

THE ELECTRIC TELEGRAPH.

CHAPTER V.

9. Current controlled by making and breaking the contact of conductors.—110. Instruments for controlling the current—commutators. 111. General principle of the commutator.—112. Its application to telegraphic operations.—113. To transmit a current on the up line only.—114. On the down line only.—115. On both lines.—116. To reverse the current.—117. To suspend and transmit it alternately.—118. *How to manage a current which arrives at a station.*—119. To *make it ring the alarum.*—120. Station with two alarums.—121. *Notice of the station transmitting and receiving signals.*—122. When *signals not addressed to* the station the current is passed on.—123.

How to receive a dispatch at the station, and stop its farther progress.—124. How several dispatches may be at the same time sent between various stations on the same line.—125. Secondary lines of wire then used.—126. Recapitulation.—127. Signals by combinations of unequal intervals of transmission and suspension.—128. Key commutator.—129. Horological commutator for a current having equal and regular pulsations.—130. Case in which the pulsations are not continuous or regular.—131. No limit to the celerity of the pulsations.—132. Application of a toothed wheel to produce the pulsations.—133. By a sinuous wheel.—134. Method of diverting the current by a short circuit, its application to the alarum.—135. Effects of the current which have been used for signals.—136. Deflection of magnetic needle.

109. SINCE all telegraphic signals depend on the power of the agent who makes them, to transmit, control, and modify the current at will, it must be apparent how important it is for those who desire to understand this interesting subject, to comprehend in the first instance the means by which this power is obtained and exercised.

It is necessary to remember that the current will flow along a line of conducting wire so long as, and no longer than, a voltaic battery is interposed at some point on the line, the wire being attached to its poles, and the remote ends of the wire connected with the earth, as explained in (23) and (36), and in that case the current will flow along the wire from earth to earth in such a direction as to enter the battery at the negative, and to leave it at the positive pole, and that provided the battery have adequate force, it does not matter how distant from its poles the points may be at which the wires are connected with the earth.

If at any point of the line the wire is broken, the current instantly ceases along the entire line. If it be reunited the current is instantly re-established. If the connection of the wire with the poles of the battery be reversed, so that the end which was connected with the positive is transferred to the negative pole, and *vice versâ*, the direction of the current along the entire line is reversed—since it must always flow *from* the positive and *to* the negative pole. If at any point the wire, being broken, be connected with another wire proceeding to the earth in any other direction, the current will be diverted to the latter wire, deserting its former course. If the wire conducting the current be connected at the same point with two wires both connected with the earth it will be distributed between the two, the greater part, however, following that wire which offers the easier road to the earth.

These few principles, which are clear and simple, supply an easy key to the whole art of electro-telegraphy.

110. The class of mechanical expedients by which the agent who desires to transmit signals is enabled to control and modify the current in the manner here described, are called by the general

name of "COMMUTATORS," and are very various in form and arrangement according to the purposes to which, and the conditions under which they are applied. Not only do apparatus of this class differ in different countries where telegraphs have been established, but they vary upon different lines, and even on different parts of the same line. Without attempting to follow these endless variations, many of which are quite unimportant, and all of which are mere varieties in the application of the general principles explained above, we shall here confine ourselves to such an illustration of them as will at the same time render intelligible their structure and operation, and convey a general notion of the manner of transmitting and receiving signals.

111. Let us suppose that around the edge of a disc of ivory, wood, or any other insulating material, are inserted at convenient intervals pieces of metal, B, U, T, D, &c., fig. 47, which we shall call *contact pieces*, their purpose being to make and break the metallic contact which controls the current. At the back of the disc near these contact pieces are clamps or tightening screws by which conducting wires can be attached to them.

To an axis in the centre of the disc let two metallic hands, A A′ be attached, so that they can be turned round the disc like the hands of a clock, but having motions independent of each other. These hands may be supposed to be formed of elastic strips of metal bent at the ends towards the surface of the disc, so as to press upon it with some force: and let one of them move over the other without disturbing it, as the minute hand of a watch moves over the hour hand. Let A″ be another similar hand, turning on a centre fixed upon the contact piece E, so that it can be turned at pleasure upon one or other of the contact pieces P or N.

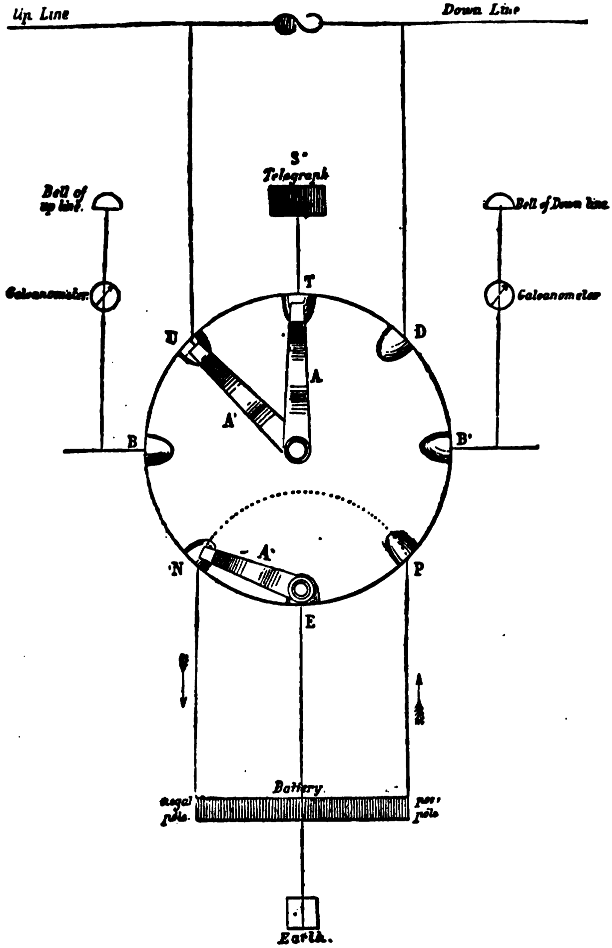
Now it is evident that by turning the hands A and A′ upon any two of the contact pieces, they will be put in metallic connection, so that a current flowing from either of them will pass by the hands to the other, and in like manner by means of the hand A″, either of the contact pieces P or N can be put in metallic connection with E.

112. To convey a general notion of the application of such an apparatus to telegraphic purposes, we shall for example suppose conducting wires connecting the several contact pieces in the following manner:—

1. P, with the positive pole of the battery.
2. N, with its negative pole.
3. E, with the earth.
4. U, with the *up-line* wire.
5. D, with the *down-line* wire.
6. B, with a bell or alarum.

It may be necessary to state here that it is customary to cal the wire which proceeds to the chief terminal station of a line th *up wire,* and that which proceeds to the secondary terminal statio the *down wire.* Thus, if a line of telegraph be extended between

Fig. 47.



London and Dover, the wire which would connect London with an *intermediate* station would *at that* station be the *up wire,* a

the wire which would connect it with Dover would be the *down wire.*

The manner in which the current arriving at any station is made to ring a bell or alarum at that station, will be explained hereafter.

In explaining the manner in which the agent at a station is enabled to control a current by means of the commutator, two cases are to be considered—first, when he desires to transmit signals; and, secondly, when he expects to receive them.

In the former case, he takes the current from his own battery; in the latter, he receives it on its arrival by the up or down line wire.

We shall first consider the case in which he desires to transmit signals.

113. *To transmit a current on the up line only.*—Let the hand A″ be placed on N, A on P, and A′ on U. The negative pole N of the battery being then in connection with the earth E by the hand A″, and the positive pole P in connection with the up wire U by the hands A and A′, while the up wire itself at the station at which it arrives is in connection with the earth, the current will flow from P by A and A′ along the up wire to the station at which the wire goes to the earth.

114. *To transmit a current on the down line only.*—Let A″ and A be placed as before, and let A′ be moved to D. The current will then flow on the down line, as may be explained in the same manner.

115. *To transmit a current along the entire line from terminus to terminus.*—Let A′ be turned upon U, and A upon N, and let two similar hands at the back of the disc be at the same time turned upon P and D, the hand A″ being removed from both N and P. In that case, the current will flow from the positive pole P along the hands at the back of the disc to D, and thence on the down wire to the terminal station, where it will take the earth, by which it will pass to the earth plate at the up terminal station, and from thence by the up wire to U, and from U by the hands A′ and A to the negative pole N.

Thus it appears that it will pass along the entire line from terminus to terminus, flowing from the up station downwards.

116. *To reverse the direction of the current.*—To accomplish this, it is obviously sufficient to reverse the connections with the poles of the battery. Thus, if the current be transmitted on the up line only, the hand A′ will be upon U, A on P, and A″ on N, when, as already explained (113), the current will flow from U towards the up station. If A″ be removed to P, and A to N, the direction will be reversed, the course of the current then being as follows:—From the positive pole P to E by the hand A″; from the earth E to the earth plate at the upper station; from that to the up wire; from thence to U, and from U by A′ and A to N.

Thus, by alternately moving the hands A″ and A between the contact pieces P and N, the current may be changed from one direction to the other on the up wire as often and as rapidly as may be desired.

The same reversion may be made in exactly the same manner on the down wire, if the hand A′ be turned upon D.

The reversion may be made with equal facility and rapidity if the current be established along the entire line by merely interchanging the position of the hands directed upon P and N, as described in 115.

117. *To suspend and transmit alternately the current during any required intervals.*—Whether the current be established on the up line or on the down line, or on both, this is easily accomplished by removing any one of the hands from the contact piece on which it rests, and restoring it to its place after the required intervals. When it is withdrawn, the current is suspended; when restored, the current is re-established. The intervals of such suspension and transmission may be as long or as short as may be desired. They may be equal or unequal. They may succeed each other with any degree of rapidity whatever. Thus there may be ten thousand intervals of suspension and ten thousand of transmission in a minute. The instantaneous character of the propagation of the electric fluid already noticed will sufficiently explain this.

118. Having thus explained how the agent controls the current in transmitting signals to a distant station, we shall now show how he treats the current which arrives from a distant station, so as to allow it to produce before him the intended signals.

The current must arrive either by the up wire or by the down wire, and therefore at either of the contact pieces, U or D.

119. *To make the arriving current give the alarm.*—When the agent at a station is not engaged in transmitting signals, he must always be prepared to receive them. A contrivance called an alarum is provided, to give him notice when signals are about to be transmitted. The alarum, which will be fully explained hereafter, is an apparatus so constructed, that whenever the current passes through it, a bell is rung, by which the attention of the agent is called.

The contact piece B is here supposed to be connected with a wire leading to such an apparatus.

When not engaged in transmitting signals, the agent connects both the up and down wires with his alarum. To accomplish this, he turns A′ upon U, and A upon B. The contact piece B being supposed to be connected with the wire which enters the alarum, the wire which issues from it is connected with B′. Two

hands, which are behind the disc, are placed one on B′ and the other on D. In this case, if a current comes down the line to U, it will pass by the hands A and A′ to B, and thence through the alarum wire to B′, whence it passes by the hands at the back of the disc to D, and thence along the down wire.

If, on the other hand, the current arrive by D, it passes in the same manner through the alarum to U, and so along the up wire.

From whatever part of the line the current may be transmitted, whether on the up or the down line, it must therefore pass through the alarum, and give notice.

120. In some cases a station is provided with two distinct alarums, one for the down and the other for the up line, having different tones, so that the agent, on hearing them, knows from which direction the signals are about to come.

In that case the wire of the up line alarum is attached to B, and that of the down line to B′, the wires which issue from the two alarums being always in such case connected with the earth.

When the agent is not engaged in transmitting, he places the hands A′ and A on U and B, and the hands behind the disc on D and B′. If a current arrive by U, it passes by B through the alarum to the earth, and gives notice. If it arrive by D, it passes in like manner through the alarum B′ to the earth, and gives notice.

It is, however, more usual to have a single alarum at each station, acting as above described.

The connections being so arranged that the current shall pass along the entire line from terminus to terminus, all the alarums at all the stations will be rung the moment the current is transmitted. General notice is therefore given that a dispatch is about to be sent from some one station along the line to some other.

121. It is necessary, however, to inform the agents at each station of the place from whence the dispatch is about to be sent, and the place to which it is to be addressed. To learn this, the agent transfers the connections from the alarum to his telegraphic instrument. This is accomplished by removing the hand A from B to T, and connecting the wire coming from the telegraphic instrument by the hands at the back of the disc with D. By this change the current passes from U to T, from T through the telegraphic instrument to D, and from thence down the line. The signals transmitted appear upon the telegraphic instrument, informing the agent whence the dispatch will come, and where it is desired to transmit it.

122. If he find that it is not to be addressed to himself, his arrangements will depend on the position which his own station *holds in relation to the two* stations between which the dispatch *is about to be transmitted*. If his station lie between them, he

turns the hands A and A′ upon the contact pieces U and D, so as to allow the current to pass between the up wire and the down wire, along the hands without interruption, and also without spending any part of its force in needlessly working his telegraphic instrument.

123. If he find that the dispatch is intended for himself, and that it proceeds from a station on the up line, for example, he places the hand A′ upon U, A upon T, and by the two hands behind the disc he connects the wire issuing from the instrument with E. By this arrangement, the current arriving at U passes by the hands A′ and A to T, thence through the telegraphic instrument to E by the hands behind the disc and to the earth.

In this case the course of the current is limited to the part of the line wire which is included between the station from which it is transmitted and that to which it is addressed. By connecting the telegraphic instrument with the earth by E, the down line wire is free; so that while the up line wire is employed in conveying the dispatch in question, other dispatches may be transmitted between any stations on the down line.

124. If we express for example the chief terminal station by S, and the series of stations upon the line proceeding from it downwards by S_1, S_2, S_3, S_4, &c., we can conceive various dispatches to be *at the same time* transmitted between them by the arrangement here explained, being made at each station which receives a dispatch. Thus, if S sends a dispatch to S_1, and S_1 cuts off its communication with the down wire by putting its telegraphic instrument in connection with the earth, the current transmitted from S stops at S_1. A dispatch may therefore be at the same time sent between S_2 and S_3, another between S_4 and S_5, and so on.

Thus, the same line of conducting wire may be at the same time engaged in the conveyance of several dispatches, the only limitation being that when a dispatch is being transmitted between two stations, no other dispatch can at the same time be transmitted between any of the intermediate stations.

It follows from this as a necessary consequence that if, as generally happens in thickly peopled tracts of country, the terminal and one or two of the most populous of the intermediate stations keep the telegraph in constant work, separate and independent wires, and instruments must be provided to serve the secondary intermediate stations, just as upon railways, second and third-class trains are provided to serve those lesser stations on the line, which are passed by the first-class trains without stopping.

Every great telegraphic line presents an example of this. Thus upon the Dover line separate wires and instruments are appropriated to the transmission of dispatches between the terminal stations, *London* and Dover, and the intermediate stations, Tonbridge,

Ashford, and Folkestone. The conducting wire passes through the telegraph offices at these three intermediate stations, but does not enter any of those of inferior importance, such as Godstone, Penshurst, Marden, Staplehurst, &c., to the service of which other conducting wires and instruments are appropriated.

125. Since, however, telegraphic communication must be provided between *all* the intermediate stations, and since the chief wires passing the chief intermediate stations do not enter the secondary ones, it follows that the wires of the secondary stations must be carried not only to the terminal stations, but also through all the chief secondary stations. Thus the wires, which pass through the stations of Godstone and Penshurst, must also pass through those of Tonbridge, Ashford, and Folkestone, since otherwise there could be no communication between the latter and the former.

From what has been already explained, it will be understood that every two secondary stations along the line can communicate at the same time with each other, no stations being compulsorily silent, except such as may lie between two communicating ones. To illustrate this, let us suppose the secondary stations from terminus to terminus of the line to be expressed by the small letters, and the chief stations, terminal and intermediate, by the capitals, in the following order:

A, *b*, *c*, *d*, *e*, F, *g*, *h*, *i*, K, *l*, *m*, *n*, O.

Now, by the secondary wires A and *b*, *b* and *c*, *c* and *d*, and so on, may at the same moment hold communication. But if A and *d* communicate, *b* and *c* can communicate neither with each other, nor with any other station. They are compulsorily silent. In like manner, if A and *m* communicate, *b*, *c*, *d*, *e*, *g*, *h*, *i* and *l* are all compulsorily silent.

Hence it will be apparent how necessary it is to put chief intermediate stations like F and K on the primary wires, since if they could communicate with A and O only by the secondary wires. frequent interruptions to the communications of all the secondary stations with each other would take place.

It will be also apparent that on lines of great intermediate business, a third or even fourth system of wires would be necessary.

This will render it easily understood why such a multiplicity of wires are seen stretching along the parts of the lines near London.

Lines of telegraph, like lines of railway, often have branches which are connected either with the primary or secondary wires of the main line, or with both, according to their importance. For example, on the main line between London and Dover, there are branches which go to Maidstone on the one side, and to Tonbridge Wells on the other. Sometimes these branch wires are provided with means of connection with the main line wires, so that the

stations on the main line can communicate *directly* with those on the branch line. Sometimes no such connection is provided, and a dispatch from the main line must be repeated at the branch station. This is a defect which ought never to be allowed to remain, inasmuch as simple and efficient commutators may always be provided for connecting the branch and main lines, which in the telegraph play a part similar to the *switches* by which trains are turned from the main to the branch line, or *vice versâ*.

It will be evident from what has been said that a dispatch transmitted upon the secondary line of wires may be delivered at the same time at all the stations from terminus to terminus along the line, or it may be allowed to pass any one or more stations without entering them, by the mere management of the commutators provided at the stations severally.

126. In what has been said, we have adverted to signals produced by the current, without explaining the nature of those signals, or the particular means by which they are produced, because all the circumstances attending their transmission from station to station, which have been explained, are quite independent of the particular character of the signals, and the way of producing them. We shall hereafter explain the character of the signals which are used, and the instruments by which they are produced.

From all that has been stated meanwhile, it may be inferred generally that by the commutating apparatus which has been described above, or by any of the endless variety of equivalent contrivances which telegraphic inventors have proposed, any of the following effects may be produced by an agent at any station, at which a current arrives:—1. Such a current may be made to pass through the alarum, and give notice to the agent of its arrival. 2. It may be made to pass through the instrument and give signals. 3. It may be made to pass the station and continue its course along the line without affecting any part of the telegraphic apparatus at the station. 4. If it pass through the alarum, or through the instrument, it may be turned into the earth, and so be prevented from going further along the line. 5. If it pass through the alarum or through the instrument, it may after leaving them be directed along the line, so as to continue its course to the other stations below or above that at which it is supposed to arrive.

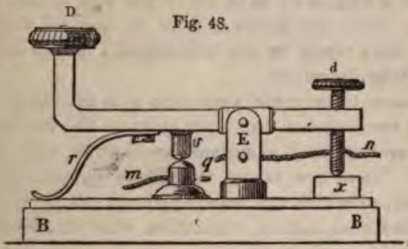
127. In some forms of telegraph, the system of signs transmitted to a distant station depends entirely upon the current being alternately suspended and transmitted for longer and shorter intervals, and this succession of long and short intervals, variously combined like the notes in music, is converted into a sort of telegraphic *language*, which by practice is expressed and understood by the

agent with as much facility and promptitude as ordinary written or spoken language.

128. In such forms of telegraph, the alternate suspension and transmission of the current is produced by a commutator, which has the form of the key of a pianoforte and is played upon in a very similar manner by the agent who transmits the dispatch.

One of the forms of these keys and the mechanism connected with it, is represented in fig. 48. It is fixed upon a wooden block

Fig. 48.



B B. The key plays upon a centre E. To the lower side of the longer arm (E D) is attached a projecting piece of metal v, called the HAMMER, under which is a fixed piece of metal of corresponding form and magnitude called the ANVIL.

The action of the key upon the current is the same precisely as that already described (117) which is produced by the alternately removing and restoring the hand to the contact piece in fig. 47. The hammer in the present case represents the hand, and the anvil the contact piece. One of the line-wires m, is attached to the anvil, and the other n to the metallic support E of the hammer and key. When the hammer is in contact with the anvil, the current passes, and when it is raised from that contact, the current is suspended.

The button D is faced with ivory to be pressed down by the finger, and the screw d passing through the short arm of the key is pressed upon the block x by the reaction of the spring r, when the key is not pressed down by the finger on D. The hammer v, and anvil q are both faced with platinum to prevent oxydation, which would obstruct that complete metallic contact which is necessary to ensure the transmission of the current.

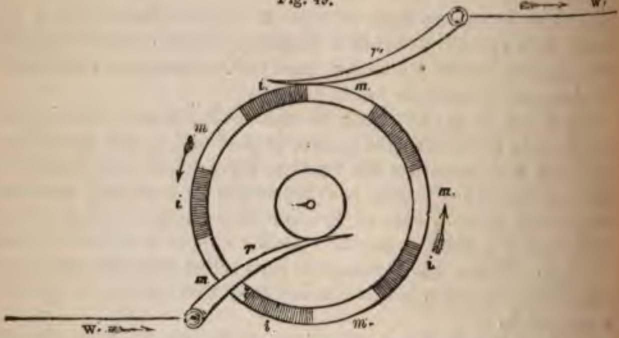
An expert manipulator can work the key D with as much celerity and correctness as can a performer on the pianoforte and can express in that way in telegraphic language any dispatch which is placed in manuscript before him, so as to transmit it to any distant station. This will be explained more fully hereafter. When no dispatch is being transmitted from the station at which

the key is placed, it is necessary to leave a free passage for the current along the line-wires m n. To effect this, the screw d, which passes through the short arm of the key, is turned so as to raise the short arm, and consequently lower the arm E D until the hammer v is brought into permanent contact with the anvil q. When that takes place, the metallic continuity between m and n will be established, and the current will flow without interruption on the line-wire. Whenever it is desired to transmit a dispatch, the screw d is turned so as to lower the arm d, and to raise E D, and thus to raise the hammer from its contact with the anvil. The key is then ready for the transmission of the dispatch in the manner already described.

129. In some telegraphic apparatus it is necessary to make the intervals of transmission and suspension of the current absolutely equal in duration, and to succeed each other with chronometric regularity. There are many expedients by which this can be accomplished, of which the following is an example.

A metallic wheel put in connection with clock-work, so as to

Fig. 49.



receive a regular motion of rotation, has its edge divided into equal parts by pieces of ivory, or some other non-conductor inlaid upon it, as represented in fig. 49, where m represents the metal, and i the ivory. A metallic spring r' connected with one end of the conducting wire W$'$, presses constantly upon its edge; and another r connected with the other end of the wire W, presses constantly on the metallic axle of the wheel which is otherwise insulated.

Now, if the wheel be supposed to have an uniform motion of revolution, the alternate divisions of ivory and metal on its edge will pass in succession under the spring r', while the spring r will be in constant metallic contact with the axis. If a current flows on the wire W, it will be transmitted by the spring r to the axle, and

thence by the metal of the wheel to r', when r' is in contact with any of the metallic parts m of the edge of the wheel, but will be suspended while it is in contact with the ivory parts i of the edge.

If the wheel, being impelled by clock-work, be moved at such a rate that each of the divisions marked m and i shall move under the spring in one second, the current will be transmitted and suspended also during intervals of one second. It will in fact be subject to a regulated pulsation, the rate of which will be controlled and determined by the horological mechanism which impels the wheel.

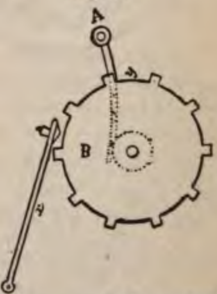
130. In some cases, the motion to be imparted to the wheel is not either regular or continuous. In such cases, it may be moved either directly by hand, or by a strap; or even by clock-work, which is subject to a check which will suspend it at certain positions of the wheel. In all these cases the pulsations of the current in number, length, and continuance, are governed by the motion imparted to the wheel.

131. As the suspension and transmission of the current are instantaneous upon the breach and re-establishment of the metallic contact of the spring r' and the wheel, there is no practical limit to the rapidity which can be given to its pulsations. The wheel may be turned, for example, so that 500 divisions of its edge may pass under the spring r' in a second, in which case there would be 250 intervals of transmission, and 250 intervals of suspension in a second.

It might perhaps be imagined that in so short an interval of time the current could not be stopped or established along the entire length of the conducting wire. It has however been shown that even with the longest continuous wires, practically used in telegraphs, the ten-thousandth part of a second is more than enough either to establish or stop the current.

132. The intervals of the suspension of the current may be produced by a common toothed-wheel, as represented in fig. 50, without ivory or other inlaid non-conducting matter. In this case, a piece of wedge-shaped metal connected with the up line wire is attached to the under side of a wooden lever, while the axle of the wheel is kept in constant metallic connection with the down wire. When a tooth of the wheel comes against the metal attached to the lever, metallic contact is established, but when the metal falls between the teeth, and the *surface of the wooden lever* rests on one of them, and the metallic *contact being broken, the current* is suspended.

Fig. 50.

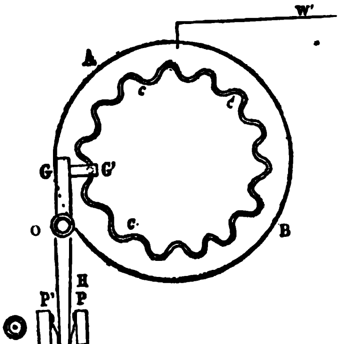


It is evident that during each revolution of the wheel there will be as many pulsations of the current as there are teeth, and since the rotation of the wheel may be as rapid as may be desired, and the teeth as numerous, there is no practical limit to the possible rapidity of these pulsations.

133. Another contrivance, by which pulsations are imparted to the current, consists of a metallic wheel around the face of which a sinuous groove is cut, in which a pin, projecting from the arm of a metallic lever is inserted, so that when the wheel is turned upon its axis, the pin attached to the lever receives from the sinuosities of the groove a motion alternately right and left, which is imparted to the other arm of the lever. This latter arm plays between two metallic stops, one of which is connected with the wire W, along which the current flows. When the arm of the lever comes in contact with it, the current is transmitted on the lever to the sinuous groove of the wheel, and from thence to the line-wire W. When the lever oscillates to the other side, the contact with the wire W is broken, and the current is interrupted.

This will be more clearly understood by reference to the fig. 51, where A B is the wheel, *c c c* the sinuous groove, G O H the lever playing on the axis O. From G, a short projecting piece, G G′, passes in front of the wheel across the groove, and from this piece a pin projects, which enters the groove. The arm H plays between two stops, P and P′, provided with springs to ensure the contact with the lever. The stop P is connected with the conducting wire W, and the groove *c* is connected with the wire W′. When the wheel is turned, the pin at G′ is driven by the sinuosities of the groove alternately right and left, by which a corresponding motion is imparted to the arm H of the lever, so that its end is driven alternately against the stops P and P′. When it is thrown against P it is in metallic connection with the wire W. When it is thrown against P′ that connection is broken.

Fig. 51.



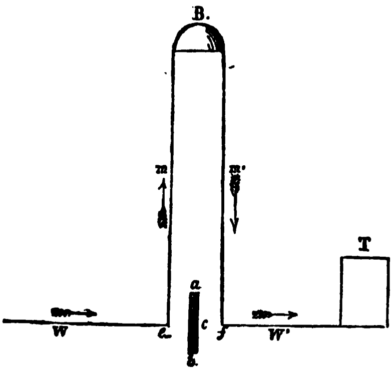
Now, if a current flow along P, it will pass to the lever when H falls against P, and will pass by the lever and the groove *c c* to the wire W′. When the arm H is thrown against P′, the contact with P being broken, the current is suspended. Thus, as the lever is

made to oscillate between P and P′, by the motion of the wheel and the action of the sinuous groove, the current will be alternately transmitted and suspended, and will, in fine, receive a succession of pulsations corresponding exactly with the sinuosities of the groove. Thus, if there be sixty undulations of the groove in the circumference of the wheel, the current will receive sixty pulsations in one revolution of the wheel, and if the wheel revolve at the rate of sixty revolutions per minute, the current will have 3600 pulsations per minute.

134. An expedient has been sometimes adopted in telegraphic apparatus for diverting the electric current from its direction, which differs in principle from the commutator, and which depends on the tendency of the current to follow the shortest and widest route open to it between one point and another.

Let W, fig. 52, be the line-wire, B the bell-apparatus, and T the telegraphic instrument. The line-wire is bent upwards in the direction *m* to the bell B, and then downwards, and by *m′* and W′ to the telegraph T. The current would, according to this arrangement, first pass by the wire *m* to the bell B, which it would ring, and then by the wire *m′* W′ to the telegraph T. If the dispatch were then transmitted, the current constantly passing through B during its transmission, the bell would be constantly ringing, which would be inconvenient as well as unnecessary.

Fig. 52.



This is prevented, and the current transmitted directly to T, without passing through B, by the following very simple expedient.

A thick piece of metal, *a b*, turns on an axis *c*, so that when it is placed in the horizontal position, the ends *a* and *b* are brought into close contact with the conducting wire at *e* and *f*. The current, on arriving at *e* divides itself into two parts, one going by *a b* to *f*, and thence to T, and the other as before, by *m*, through the bell. But as *a b* is much shorter and thicker than the wire *m m′*, the greater part of the current will go by *a b*, and the part which passes along *m m′* will be too inconsiderable to exercise the force necessary to ring the bell.

The agent, therefore, at the station, receiving the dispatch, being warned by the bell that the agent at the station wants to send a dispatch, turns the piece *a b* into the horizontal position, and the bell ceases to ring, the telegraph T receiving the dispatch.

135. The manner in which the pulsations of the current are produced, controlled, and regulated, by the operator at the station S″ being understood by these examples and illustrations, it will next be necessary to show how they are made to produce signals at the station to which the dispatch is transmitted, by which the operator or observer there can be enabled to understand and interpret the communication.

The effects of the current which have been found most convenient for this purpose are—

1st. Its power to deflect a magnetic needle from its position of rest, and to throw it into another direction.

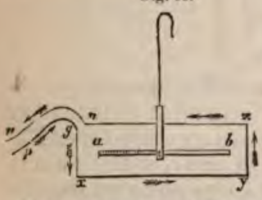
2nd. Its power to impart temporary magnetism to soft iron, this magnetism suddenly deserting the iron when the current is suspended.

3rd. Its power to produce the chemical decomposition of certain substances.

136. All forms of electric telegraph depending on one or other of these properties of the current, it is indispensably necessary to understand them before the reader can hope to comprehend the mode of operation of these wonderful instruments.

If a wire be extended over and under a compass-needle which directs itself to the magnetic north and south, parallel to the needle, and as close to it as it can be placed without actually touching it, as represented in fig. 53, the needle will remain undisturbed in its position. Let the ends *p* and *n* of the wire be then attached to the poles of a voltaic battery, so that a current of a certain intensity shall be transmitted upon it. The moment the current is established upon the wire, the magnetic needle *a b* will be thrown out of its usual direction, and instead of pointing north and south, it will point east and west.

Fig. 53.



If the direction of the current upon the wire be reversed, the direction of the deflexion of the needle will be reversed.

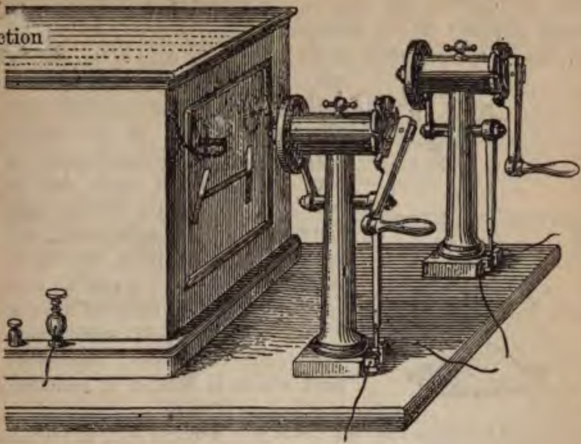


Fig. 72.—FRENCH STATE TELEGRAPH.

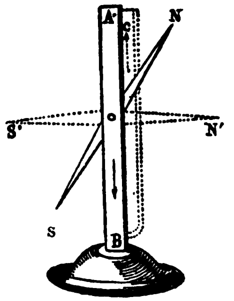
THE ELECTRIC TELEGRAPH.

CHAPTER VI.

137. Relation of the deflection to the direction of the current.—138. Galvanometer or multiplier.—139. Method of covering the wire.—140. Method of mounting the needle.—141. Method of transmitting signals by the galvanometer.—142. How the current may produce a temporary magnet.—143. Electro-magnet constructed by Pouillet.—144. Electro-magnets formed by two straight bars.—145. They acquire and lose their magnetism instantaneously.—146. Magnetic pulsations as rapid as those of the current.—147. How they are rendered visible and counted.—148. Extraordinary celerity of the oscillations thus produced.—149. They produce musical sounds by which the rate of vibration may be estimated.—150. How the vibrations may impart motion to clock-work.—151. Their action on an escapement.—152. How the movement of one clock may be transmitted by the current to another.—153. How an electro-magnet may produce written characters on paper at a distant station.—154. How the motion of the hand upon a dial at one station can produce a like motion of a hand upon a dial at a distant station.—155. How an agent at one station can ring an alarum at another station.—156. Or may discharge a gun or cannon there.—157. Power of the bell or other signal not dependent on the force of the current.—158. Mechanism of telegraphic alarum.—159. Various alarums in telegraphic offices.—*160. Magneto-electricity.*—161. Method of producing a momentary *magneto-electric current.*—162. Application of an electro-magnet to *produce it.*

137. To explain the manner in which the deflection of the needle depends on the direction of the current, let us suppose the needle to be placed on an horizontal axis O, fig. 54, so as to play in a vertical plane, and to be maintained in the vertical direction when not affected by the current, by giving a slight preponderance to the arm on which the south pole of the needle is placed. By this arrangement the needle, when undisturbed, will rest in the vertical position, the north pole N being directed upwards, and the south pole S being directed downwards.

Fig. 54.



Now if the current which is before the needle be directed *downwards* and that which is behind it *upwards*, the *north* pole N will be deflected to the *right*, and consequently the *south* pole S to the *left*, as represented in the figure. But if the direction of the current be reversed so that *before* the needle, it shall be directed *upwards* and *behind* it *downwards*, the north pole N will be deflected to the left and the south pole S to the right.

If the intensity of the current be great, and the preponderance given to the lower arm of the needle small, the deflective force of the current will be sufficient to throw the needle completely at right angles to its position of rest, that is, to give it the horizontal direction; but it is important to observe, that no greater intensity of the current can affect it further. The north pole, for example, cannot be deflected downwards, or the south pole upwards. In fine, the needle cannot be more affected by any increase of force of the current after it has once been thrown into the horizontal direction.

If the intensity of the current be insufficient to throw the needle into the horizontal direction, it will nevertheless take a position intermediate between that and the vertical direction at which it will rest. Its deflection from the vertical will be more and more considerable as the current is more intense, and certain mathematical conditions have been discovered by which the relative intensity of the current may be determined by the amount of the deflection of the needle which it produces.

138. It is evident that the sensibility of the needle will be so much the greater as the preponderance of the arm S is diminished and the intensity of the current increased. An expedient has, however, been ingeniously contrived, by which the most feeble current can be made to affect the needle. This is accomplished by

winding the wire which carries the current several times round the needle, each coil being still parallel to the needle. By this contrivance, each successive coil of the wire produces a separate effect upon the needle, and if there be fifty such coils passing successively before and behind the needle, each portion of the wire thus carrying the current producing an independent deflecting force, there will be a total deflecting force an hundred times greater than that which a single portion of the wire, passing once over or under the needle would produce.

In this manner the deflecting power of the most feeble current may be so *multiplied* as to produce upon the needle as powerful an effect as would be produced by a current of great intensity.

An apparatus consisting of wire thus coiled round a magnetic needle is called a MULTIPLIER, inasmuch as it multiplies the deflecting power of the needle. It is also called a REOSCOPE, or REOMETER,* and sometimes a GALVANOSCOPE, or GALVANOMETER, inasmuch as it indicates the presence, and by certain arrangements, measures the intensity of a galvanic or voltaic current.

139. When the conducting wire is thus coiled round a needle, it is necessary that it should be covered or coated by some substance which is a non-conductor of electricity, since otherwise the coils being necessarily in contact one with another, the current, instead of following the continuous thread of wire, would pass from coil to coil. In such cases, therefore, the wire is wrapped with silk or cotton, which being a non-conductor, confines the current within it just as water would be included in a pipe.

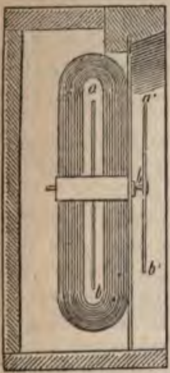
140. As the wire coiled in the manner above-described, and the frame which carries it, would prevent the play of the needle from being easily and conveniently observed, the needle included within the frame is fixed upon the axis which supports it, so that the axis turns with it. This axis passes through the side of the frame, on which the wire is coiled, and upon the end of it which projects beyond the frame a hand is fixed, so as to be parallel to the needle, the play of which will necessarily correspond with that of the needle. This hand plays upon a sort of dial, by which its deviations to the right or to the left, from its position of rest are indicated.

This will be more clearly understood by reference to fig. 55 (p. 196), which represents a section of the mounting of the needle, the coil of wire and their appendages, made by a vertical plane through the axis of the needle. The needle within the coil is represented at a b, in its position of rest. The axis of the needle

* From two Greek words, ρεος (reos) a current, and μετρον (metron) a measure.

passing through the frame supporting the coil, and through the dial plate, supports in front of the dial the hand a' b', which is fixed upon the axis in a position parallel to the needle a b, so that it must play before the dial in a manner corresponding exactly with the play of the needle a b within the coil.

Fig. 55.



141. In order to govern the play of the needle, it is necessary that the agent at the station from which the signal is transmitted should have the power, 1st. To suspend and transmit the current at the receiving station; and 2nd. To change its direction upon the conducting wire. The former is necessary, to enable him to bring at all times the needle to its position of rest; and the latter, to deflect it to the right or to the left, according to the exigencies of the telegraphic communications.

The general principle on which these changes in the flow and direction of the current are effected, has been already explained (111). It is easy to imagine, that by very simple mechanism the movement of a lever or arm may make or break the contact of the conducting wires, so as to transmit or suspend the current at pleasure. Also by a simple motion of such an arm the hands, A and A″, fig. 48, or any equivalent pieces, may be moved from P to N and from N to P, so as to reverse the current upon the wire to which the arm A′ is directed.

If then an agent at the station, S″, for example, be provided with any means of suspending or reversing the current which passes along the wire, between S and S″, he can at will bring a magnetic needle, mounted at S, to its position of rest, that is, to the vertical position, by suspending the current or deflect it to the right, by causing the current to flow in one direction on the conducting wire, or to the left, by reversing the direction of the current.

The particular manner in which these several operations subserve to telegraphic purposes will be presently explained.

Fig. 56.

142. To explain the manner in which the electric current can impart temporary magnetism to soft iron, let us suppose a copper wire wrapped with silk, to prevent the metallic contact of contiguous convolutions, to be coiled round a rod of soft iron, bent into the form of a horse-shoe, as represented in fig. 56, care being taken, that in carrying the wire from one arm to the other, the

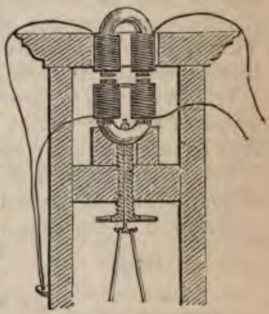
direction of the convolutions shall be the same as if the coils had been continued round the bend.

So long as no electric current passes along the convolutions of the wire the horse-shoe will be free from magnetism. But if the ends of the wire, marked + and —, be put in connection with the poles of a voltaic battery, so that a current flow round its convolutions, the horse-shoe will instantly become a magnet, and will be so much the more powerful as the current is more intense, and the coils more multiplied.

If an armature loaded with a weight be presented to the ends of the horse-shoe while the current passes on the wire, it will adhere to them, and the weight, if not too great, will be supported.

143. In 1830 an electro-magnet of extraordinary power was constructed under the superintendence of M. Pouillet, at Paris. This apparatus, represented in fig. 57, consists of two horse-shoes, the legs of which are presented to each other, the bends being turned in contrary directions. The superior horse-shoe is fixed in the frame of the apparatus, the inferior being attached to a cross-piece which slides in vertical grooves formed in the sides of the frame. To this cross-piece a dish or plateau is suspended in which weights are placed, by the effect of which the attraction which unites the two horse-shoes is at length overcome. Each of the horse-shoes is wrapped with 10,000 feet of covered wire, and they are so arranged that the poles of contrary names shall be in contact. With a current of moderate intensity the apparatus is capable of supporting a weight of several tons.

Fig. 57.



144. It is found more convenient generally to construct electro-magnets of two straight bars of soft iron, united at one end by a straight bar transverse to them, and attached to them by screws, so that the form of the magnet ceases to be that of a horse-shoe, the end at which the legs are united being not curved but square. The conductor of the heliacal current is usually a copper wire of extreme tenuity.

145. In whatever form these magnets are constructed, the circumstance *which in* their telegraphic use is of most importance *to notice, is that if* proper conditions be observed in their preparation, their acquisition of the magnetic virtue upon the

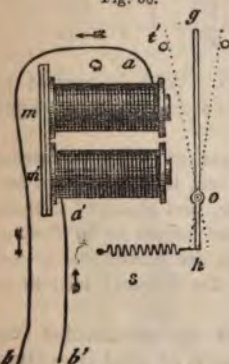
establishment of the current, and their loss of it upon the suspension of the current, are, for all practical purposes, instantaneous. The moment the extremities of the wire coiled round the horse-shoe are put into connection with the poles of the battery the horse-shoe becomes a magnet, and the moment the connection with the battery is broken it loses the magnetic virtue.

146. It has been already shown, that by means of very simple expedients, the current may be interrupted hundreds or even thousands of times in a second, being fully re-established in the intervals. The acquisition and loss of magnetism by the horse-shoe accompany these pulsations with the most perfect and absolute simultaneity. If the pulsations of the current be produced, at the rate of a thousand per second, the alternate presence and absence of the magnetic virtue in the horse-shoe will equally be produced at the rate of a thousand per second. Nor are these effects in any way modified by the distance of the place of interruption of the current from the magnet. Thus, pulsations of the current may be produced by an operator in London, and the simultaneous pulsations of the magnetism may take place at Vienna, provided only that the two places are connected by a continuous series of conducting wires.

147. It remains to show how these rapid pulsations of the magnetism of the bar can be rendered sensible, and how they may even be estimated and counted.

Let two straight rods of soft iron be surrounded by a succession of convolutions of covered wire, such as has been already described, and let the ends, *m*, *m′*, fig. 58, of these rods be connected by a straight bar of soft iron, attached to them by screws and nuts. Let the wire, *a b*, proceeding from a distant station, S, be put in metallic connection with the extremity of the wire coiled upon the rod, *m*, and let the wire, *a′ b′*, connected with the extremity of the last convolution of the wire on the rod, *m′*, be put in metallic connection with the earth. If a current flow along *a b*, it will therefore circulate round the rods, *m* and *m′*, and will pass to the earth by the wire, *a′ b′*. So long as this current flows, the rods will be magnetic, and they will lose their magnetism in the intervals of its suspension.

Fig. 58.



Let *g h* be a light iron bar, supported on a pivot, at *o*, on which it is capable of playing, so that its arm, *o g*, may move freely to

the right or left. Let t t' be two stops, placed a small distance to the right and left of its extremity, g, so as to limit the range of its play. Let s be a spring attached to the extremity, h, by which that extremity will be constantly drawn to the left, and therefore the opposite extremity, g, thrown to the right against the stop, t. When the current is suspended, and the rods, m m', divested of magnetism, the lever yielding to the action of the spring, s, the end, g, will rest against the stop, t. But when the current passes on the wire, the rods, m m', becoming magnetic, will attract the arm, o g, of the lever, and this attraction exceeding the force of the spring, the arm, o g, will be drawn towards the electro-magnet, until it encounters the stop, t', against which it will rest so long as the current continues to flow. But the moment the current is suspended, the bars, m m', suddenly losing their magnetism, the lever, o g, is abandoned to the action of the spring, and it is again thrown back upon the stop, t, where it rests until the current is re-established.

Let us suppose that an agent at the station, s, to which the wire, a b, extends, and which may be at any distance, 500 miles for example, from s″, is supplied with any of the means which have been explained, by which he can at will control the pulsations of the current. When he causes the current to flow, he imparts magnetism to the bars, m m', and throws the lever, o g, against the stop, t'. When he suspends the current he deprives the bars, m m', of their magnetism, and leaves the lever, o g, to the action of the spring, s, by which it is thrown against the stop, t.

It appears, therefore, that with each pulsation which the current receives from the agent at s, the lever, o g, at s″, 500 miles distant from him, will perform a vibration between the stops, t and t'. As the transmission and suspension of the current, and also the acquisition and loss of the magnetic power, by the rods, m m', are both instantaneous, there is no practical limit to the velocity of the pulsations of the current and those of the magnetism alternately acquired and lost by the rods, m m'. The oscillations of the lever, o g, produced by these pulsations are limited, however, by the weight of the lever, the force of the spring, and the distance between the stops, t and t'. The greater the weight of the lever, the force of the spring, and the distance between the stops, the slower will be the motion of the lever from t to t', produced by a current of given intensity. The greater the weight of the lever, and the distance between the stops, and the less the force of the spring, *the slower will be* the motion from t' to t.

The stop, t', is so placed as to prevent the absolute contact of *the arm of the lever* with the electro-magnet, but to allow it to

approach the latter very closely. Absolute contact is to be avoided, because it is found that in that case the arm adheres to the magnet with a certain force after the current ceases to flow, but so long as absolute contact is prevented, it is immediately brought back by the spring, *s*, when the current is suspended.

148. It is evident, therefore, that the limit of the possible celerity of vibration to be imparted to the lever, *o g*, by the pulsations of the current will depend on the nice adjustment of the weight and play of the lever, and the force of the spring, *s*.

The velocity of oscillation, however, which can in this way be imparted to the lever, is such as can scarcely be credited without actually witnessing its effects. When that velocity does not exceed a certain limit the oscillations may be registered and counted, by causing the lever to give motion to the anchor of an escapement, connected with a train of wheel-work, by which a hand or index, moving on a graduated dial, is governed. But these oscillations are susceptible of velocities so great that it would be difficult to apply this expedient for counting them. M. Gustave Froment, of Paris, suggested and applied to this purpose with complete success, a method of ascertaining the velocity depending on the laws which govern the vibrations of musical strings.

149. It is well known that the pitch of any musical note is the consequence of the rate of vibration of the string by which it is produced, and that the more rapid the vibration the higher the note will be in the musical scale, and the slower the vibration the lower it will be. Thus the string of a pianoforte which produces the bass note  vibrates 132 times in a second, that which produces the note  vibrates 66 times in a second, and that which produces the note  vibrates 264 times per second.

On a seven octave pianoforte the highest note in the treble is three octaves above , and the lowest note in the bass is four octaves below it. The number of complete vibrations corresponding to the former must be 3520; and the number of vibrations per second corresponding to the latter is $27\frac{1}{2}$.

If, therefore, the lever, *o g*, have any rate of vibration more rapid than $27\frac{1}{2}$ vibrations per second, and less rapid than 3520 per

second, it will produce by its motion some definite musical sound, and if the note formed upon a pianoforte, which is in unison with it, be found, the rate of vibration of the string producing that note, will be the same as that of the lever.

When it is stated that the vibrations imparted by the pulsations of the current to levers, mounted in the manner here described, have produced musical notes nearly two octaves higher than the highest note on a seven octave piano, tuned to concert pitch, it may be conceived in how rapid a manner the transmission and suspension of the electric current, the acquisition and loss of magnetism in the soft iron rods, and the consequent oscillation of the lever, upon which these rods act, take place. The string which produces the highest note, on such a piano, vibrates 3520 times per second. A string which would produce a note an octave higher would vibrate 7040 times per second, and one which would produce a note two octaves higher would vibrate 14080 times per second.

It may, therefore, be stated, that by the marvellously subtle action of the electric current, the motion of a pendulum is produced, by which a single second of time is divided into from twelve to fourteen thousand equal parts!

150. It has been already shown how the motion of clock-work may be applied to control and regulate the pulsations of the electric current. We shall now show how, on the other hand, the pulsations of the current may be made to govern the motion of wheel-work. This expedient must be regarded with the more interest inasmuch as it has been applied with the greatest effect in several of the varieties of electric telegraph, which have been proposed or brought into operation.

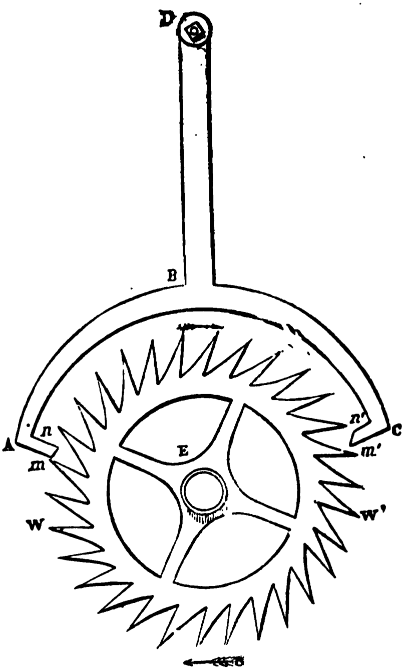
151. If we suppose the lever $g\,h$, fig. 58, to be put into connection with the anchor of the escapement wheel of a system of clock-work, it will be easy to see how that clock-work can be regulated by the pulsations of the electric current.

In fig. 59 (p. 202), W W′ is the escapement wheel which is constantly impelled by the force of a descending weight or mainspring in the direction of the arrows. The anchor A B C, of the escapement, is connected with an axis D, by the straight rod B D. This rod B D may be either the vibrating arm of a lever, such as $g\,h$, fig. 58, kept in oscillation by the current acting on an electro-magnet, or it may be connected with such a lever in any convenient manner, so as to oscillate simultaneously with it, and to have the extent of play necessary for the action of the pallets A and C of the anchor on the teeth of the escapement wheel.

When the anchor is not in a state of oscillation, a tooth of the wheel will rest upon one of its pallets, and the wheel and clock-work connected with it will be stopped. When the anchor moves

from left to right, the tooth of the wheel, which was previously stopped by the upper surface *n'* of the pallet C, is allowed *to escape*,

Fig. 59.



and in obedience to the power of the spring or weight, which moves the clock-work, it advances towards *m'*. Meanwhile the pallet A enters the space between two teeth of the wheel, one of which coming against its lower surface, it stops its motion. When the anchor moves back from right to left, the pallet C comes under the next tooth of the wheel. In this manner every movement of the anchor to the right lets a tooth, which was stopped by the pallet C, advance, and afterwards the pallet A stops the advance of another tooth, while every movement to the left lets the tooth stopped by A advance, and afterwards the pallet C stops the next tooth which advances on that side.

Thus each complete oscillation of the anchor, consisting of a motion to the right and a motion to the left, lets one tooth of the escapement wheel, and no more, pass.

Now if we suppose the pulsations of the current to impart to the anchor by the intervention of the electro-magnet and its appendages a motion of vibration, a tooth of the escapement wheel, and no more than one tooth, will pass the anchor for each pulsation of the current. If the current be suspended the movement of the escapement wheel and the clock-work connected with it will be also suspended, and when the pulsation of the current *recommences*, the oscillations of the anchor, and consequently the *motion of the* escapement wheel, and the clock-work connected *with it*, will also recommence.

152. If the pulsations of the current be regulated (as they may

be according to what has been already explained (129), by the pendulum of a clock at any station, the motion of the anchor of the escapement established at any other station to which the current is transmitted, will be synchronous with that of the pendulum of the clock which governs the pulsations of the current, and thus a regular motion may be imparted by one clock to another, provided that between them there be established a conductor, and the pendulum of the one clock regulates the pulsations of the current, which govern the movement of the anchor of the escapement of the other.

153. If the extremity of the lever, *og*, fig. 58, carry a pencil, which presses upon paper, when the lever is drawn towards the electro-magnet, and if at the same time the paper is moved under the pencil with an uniform motion, a line will be traced upon the paper by the pencil, the length of which will be proportionate to that of the interval during which the lever *o g* is held in contact with the stop *t'*. Now as the agent at s can regulate this interval at will, by controlling the flow of the electric current, making that current act for a short interval if he desire to make a short line upon the paper, for a long interval if he desire to make a long line, and for an instant if he desire to make merely a dot, it will be understood how he can at will mark a sheet of paper at s″, 500 miles distant, with any desired succession of lines of various lengths or of dots, and how he may combine these in any way he may find suitable to his purpose.

We have here supposed the pencil attached to the end of the lever to be alternately pressed against the paper, and withdrawn from it by the motion of the lever. If, however, the paper be so placed that the lever shall oscillate parallel to it, the pencil presented to the paper will remain permanently in contact with it, and will trace upon the paper a line alternately right and left, whose length will be equal to the play of the end *g* of the lever, to which the pencil is attached. If while this takes place the paper be moved under the pencil in a direction at right angles to the line of its play, the pencil will trace upon the paper a zigzag line, the form of which will depend on the relation between the motion of the paper and that of the pencil. When the current is in this case suspended, the paper being moved under the pencil at rest, a straight line will be traced upon it.

Thus the paper will be marked either with a zigzag line, or a straight line according as the current is transmitted or suspended.

If the current be alternately transmitted and suspended during intervals of unequal length, at the will of the agent, at s, the paper at s″ will be marked by a line alternately zigzag and

straight, the length of the zigzag and straight parts being varied at the will of the operator at s.

How these subserve to telegraphic purposes will be presently more fully explained.

154. In the same manner, if a toothed wheel, moved by the agent at s, produce a pulsation of the current by the passage of each successive tooth, these pulsations will produce simultaneous oscillations of the lever *o g*, at the station s″, and if these oscillations act upon the anchor of an escapement wheel attached to clock-work at s″, that wheel will be advanced in its revolution, tooth for tooth, with the wheel at s, and if each of these wheels govern the motions of hands upon dial plates, like the hands of a clock, the hand of the dial at s″ will have the same motion exactly as the hand on the dial at s, so that if at the commencement of the motion both hands point to the same figure or letter of the dial, they will continue, moving together, to point always to the same figures or letters.

Thus if the operator at s desire to direct the hand on the dial at s″, to the hour of 3 or 5, he will only have to turn the hand upon the dial, at his own station, to the one or the other of these hours.

It will presently also be apparent how important this is in the art of electro-telegraphy.

155. If the lever *o g*, fig. 58, be connected with the tongue of an alarum-bell, so that when *o g* is put into vibration the bell will ring, and will continue to ring so long as the vibration is continued, it is evident that the operator at s can, at will, ring a bell at s″, by producing pulsations of the current in any of the ways already described.

An operator at s″ may in like manner ring a bell at s.

By this mutual power of ringing bells, each operator can call the attention of the other, when he is about to transmit a dispatch, and the other by ringing in answer can signify that he is prepared to receive the dispatch, as already stated.

156. If the lever *o g* were in connection with the lock or other mechanism, by which the powder charging a cannon is fired, the operator at T could at will discharge a cannon at R, no matter what may be the distance of R from T.

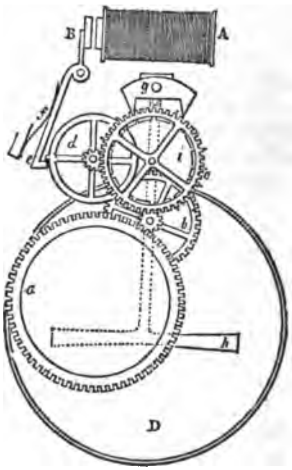
157. It will be observed that when a bell is rung, or any similar signal produced at the station s″, by means of an electric current transmitted from a distant station, s, it is not directly the force of the current which acts upon the object by which the signal is made. The current is only indirectly engaged, producing the result by liberating the mechanism which makes the signal and leaving the force which moves it free to act. Thus in the most usual case of a bell, it is acted upon while it rings, not by the

current, but by the force of a mainspring or descending weight, transmitted to the hammer or tongue in the same manner exactly as that in which the force of a mainspring or weight of a clock is transmitted to the striking apparatus. The current does nothing more than disengage a catch by which the motion of the wheel-work acted on by the mainspring or weight, is arrested. The catch once disengaged, the action of the current on the bell ceases, and the ringing is continued by the action of the mainspring or weight, and it may in like manner be stopped by the current again throwing the catch between the teeth of one of the wheels.

It will, therefore, be apparent that since the force which impels the bell is independent of the current, a bell of any desired magnitude may be acted upon by a hammer of any desired weight, without requiring any more force from the current than that which is sufficient to enable the electro-magnet to disengage the catch by which the mechanism of the bell is arrested.

158. Although the bell mechanism used for telegraphs differs in nothing which is essential from that of a common alarum clock, it may not be without interest to show one of the varieties of mechanism in practical use.

Fig. 60.



In fig. 60 is given a view of the bell mechanism, as used on the telegraphic line of the South-Eastern Railway Company.*

A is the electro-magnet.

B its armature.

B *e* a lever attached at the upper end to the armature, and having at the lower end a catch, *e*, which when the armature is not attracted towards the magnet is pressed by a spring, *f*.

d a wheel having a tooth in which the catch *e* is engaged by the pressure of the spring *f*, when the armature B is not attracted towards the magnet, but which is liberated from the catch *e*, when the armature B is drawn towards the magnet.

a a cylindrical box containing a strong mainspring, by which the train of wheelwork is kept in motion so long as the catch *e* is not engaged in the tooth of the wheel *d*.

* Elect. Tel. Manip., p. 23.

The actual contact of the armature B with the poles of the electro-magnet is prevented by two small ivory knobs screwed into the surface which is presented to the magnet. The play of the armature B is so limited that the catch *e* shall be just disengaged from the tooth of the wheel *d*, when the ivory knobs come into contact with the poles of the magnet.

When the wheel-work is liberated by the magnet withdrawing the catch *e* from the wheel *d*, the mainspring in the cylindrical box *a* causes the toothed wheel attached to the box to revolve. This wheel drives a pinion on the axle of the wheel *b*; the wheel *b* drives a pinion on the axle of the wheel *c*; the teeth of the wheel *c* are engaged with those of a pinion on the wheel *d*. The movement of the train is stopped, when the catch *e* falls under the tooth of the wheel *d*. The wheel *i*, which is engaged in the anchor of the escapement *g*, is fixed upon the axle of the wheel *c*, turns with the latter, and thus gives an oscillating motion to the anchor, which is imparted to the hammer *h* of the bell D. The bell is therefore acted upon by the hammer so long as the magnet A keeps the catch *e* from falling under the tooth of the wheel *d*.

159. Since the magnitude, loudness or pitch of the bell is independent of the force of the current, the telegraphic offices are provided with various bells for special purposes.

Sometimes a special wire is appropriated to the bell which is acted upon by a special current.

In other cases the regular current intended to work the telegraph is diverted to the bell apparatus by the commutator. In other cases again, the object is accomplished by the expedient explained in (134), which is known as the *short circuit*.

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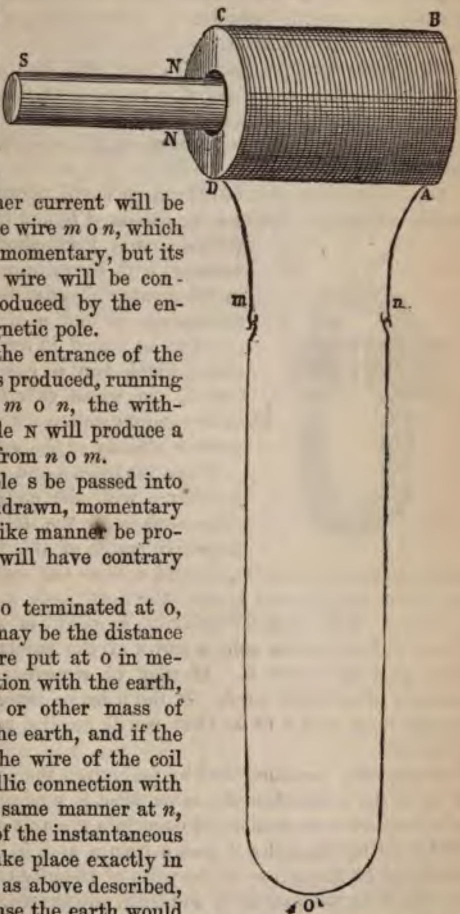
160. Having explained the form and construction of electro-magnets, we are prepared to show the manner in which an electric current may be produced by the mere action of magnets without any intervention of a voltaic battery.

The electricity thus produced has been called MAGNETO-ELECTRICITY.

161. Let a silk or cotton covered wire be coiled heliacally on a roller or bobbin having a hollow core of sufficient magnitude to allow a cylindrical bar to be passed into it. Let the covered wire be coiled constantly in the same direction, beginning from A B, (fig. 61), and terminating at C D. Let the extremities *m n* of this wire be joined to those of a wire *m* O *n* of any required length, stretched to any required distance. Now let the north pole N of a magnet S N be suddenly passed into the core of the

bobbin. An electric current will then be transmitted on the wire *m* o *n*, the presence of which may be rendered manifest by a galvanometer. This current, however, will be only momentary, being manifested only at the moment the pole of the magnet enters the core of the bobbin. It ceases immediately after that entrance.

Fig. 61.



Now if the magnetic bar after entering be as suddenly withdrawn, another current will be produced upon the wire *m* o *n*, which will also be only momentary, but its direction on the wire will be contrary to that produced by the entrance of the magnetic pole.

Thus if upon the entrance of the pole N a current is produced, running in the direction *m* o *n*, the withdrawal of the pole N will produce a current running from *n* o *m*.

If the south pole S be passed into the core and withdrawn, momentary currents will in like manner be produced, but they will have contrary directions.

If the wire *m* o terminated at o, no matter what may be the distance of o from *m*, were put at o in metallic communication with the earth, or with a plate or other mass of metal buried in the earth, and if the extremity *n* of the wire of the coil were put in metallic connection with the earth in the same manner at *n*, the transmission of the instantaneous currents would take place exactly in the same manner as above described, because in that case the earth would play the part of a *conductor* between the end of the wire *m* o at o, and *the end of the coil wire n*.

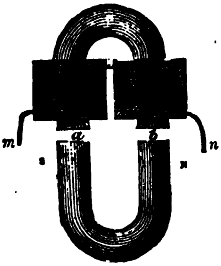
But if the metallic continuity either of the wire *m* o *n*, in case it

extended from *m* to *n*, or of *m* o if it were as described above in connection with the earth at o, were anywhere broken, no current would be produced by the entrance or withdrawal of the magnet. It is therefore essential to the production of these phenomena that the extremities *m* and *n* of the coil wire shall be in electric communication with each other, by being united either with a continuous metallic connection, or by means of the earth in the manner already described.

The property in virtue of which soft iron acquires magnetic properties, when the poles of a permanent magnet are brought into proximity with it, supplies a very convenient method of exhibiting the play of the phenomena of momentary currents above described.

162. Let S O N (fig. 62), be a powerful permanent horse-shoe magnet, having its poles S, N, presented to and in close proximity with a similar horse-shoe *a b* of soft iron, wrapped with convolutions of covered wire in the manner already described. Let the extremities *m* and *n* of the coil be supposed to be placed in connection with two wires, which may be extended to any distances, and whose extremities are in metallic communication with the earth in the manner already explained.

Fig. 62.



When the poles S and N are brought into proximity with the ends *a* and *b* of the horse-shoe *a b* the latter will, by the inductive action of the magnet S O N, acquire magnetic polarity, the end *a*, near the south pole S, having northern, and the end *b*, near the north pole N, having southern polarity. This magnetic polarity, however, of *a b* will only continue so long as the poles S and N of the permanent magnet are kept near to *a* and *b*. If they be removed, that instant the polarity of *a b* will cease. If the poles be reversed, N being presented to *a*, and S to *b*, then *a* will acquire south, and *b* north polarity.

It appears, therefore, that by presenting the poles of the magnet N O S to the horse-shoe the same effect is produced as if the poles of a magnet were suddenly passed into the axis of the coil, and by withdrawing the poles N and S from *a* and *b*, the same effect is produced on the coil as if the poles of the magnet which had been passed along the axis were suddenly withdrawn.

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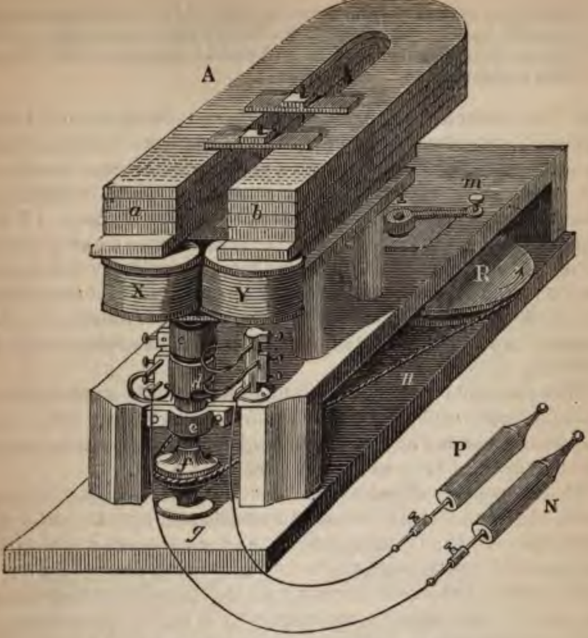

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THE ELECTRIC TELEGRAPH.

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163. The momentary currents in the one direction or in the other will, therefore, be produced upon the wire connected with the extremities of the coil, such as have already been described, each time the poles, N and S, are presented to and withdrawn from the ends, *a* and *b*, of the horse-shoe of soft iron. If the magnet, N O S, were mounted so as to revolve upon an axis passing through the centre of its bend, and therefore midway between its legs, its poles might be made to pass the ends of the horse-shoe, the latter being stationary. During each revolution of the magnet, N O S, the polarity imparted to the horse-shoe would be reversed.

When the pole N approaches *b*, and consequently S approaches *a*, south polarity will be imparted to *b*, and north polarity to *a*; and when N passes *a*, and consequently S passes *b*, south polarity will be imparted to *a*, and north polarity to *b*.

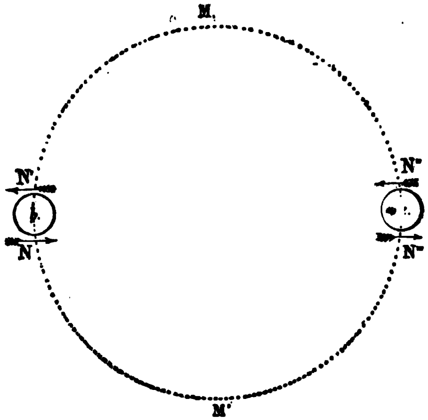
The momentary currents produced by these changes of magnetism in *a* and *b* will be easily understood by what has been explained. When N approaches *b*, and S approaches *a*, the commencement of south polarity in *b*, and north polarity in *a*, will both impart to the wire a current in the same direction, because the coils of the spiral as presented to S will be the reverse of those presented to N. When N departs from *b*, and S from *a*, the cessation of south polarity in *b*, and of north polarity in *a*, will impart currents in the same direction to the wire, but this direction will be opposite to that of the former currents.

When N approaches *a*, and consequently S approaches *b*, currents will be imparted to the wire whose direction will be the same as that of those produced by the departure of N from *b*, and of S from *a*. When N departs from *a*, and S from *b*, currents will be produced in the same direction as when N approaches *b* and S approaches *a*.

If the direction of the currents produced when N approaches *b*, and S approaches *a*, be indicated by an arrow directed to the right, and that of those produced when N departs from *b*, and S from *a*, by an arrow directed to the left, the changes of direction which take place in each revolution of the magnet N O C, will be such as are indicated in fig. 63, where *b* and *a* represent the ends of the horse-shoe, *b a*; N the position of the pole in approaching, and N′ in departing from *b*, and N″ its position in approaching, and N‴ in departing from *a*. The arrows directed to the right express the direction of the two

currents which are produced upon the conducting wire, while N makes the half revolution N''' M' N; and the arrows directed to

Fig. 63.



left express the direction of the two currents produced, while N makes the half revolution N' M N''.

Thus it appears that in each revolution of the magnet, N O S, four momentary currents are produced in the wire, two in one direction during one semi-revolution, and two in the contrary direction during the other semi-revolution. In the intervals between these momentary currents there is a suspension of voltaic action.

164. It has been already shown how electric currents may be instantaneously suspended, re-established, and reversed in their direction by means of commutators (111). By such an expedient properly adapted, it is easy to understand that by suspending the currents in one of the two contrary directions, while the other is allowed to pass, an intermitting current always running in the same direction may be obtained. Or if the commutator be so adapted that while the momentary currents in one direction are allowed to run without interruption, those in the other direction shall be reversed, we shall then have in each revolution four momentary currents flowing in a common direction. The current thus produced will be intermitting, that is, it will pass upon the wire by a succession of pulsations or intervals of transmission and suspension, but since in each revolution of the magnet there are two pulsations,—that is, two intervals of transmission and two of

suspension,—and since the rotation of the magnet may be made with any desired rapidity, it follows that the pulsations will succeed each other with such celerity, and the intervals of suspension will be so brief that for all practical purposes the current will be continuous.

165. Such are the principles on which is founded the construction of magneto-electric machines, one form of which is represented in fig. 64 (page 1). The purpose of this apparatus is to produce by magnetic induction an intermitting current constantly in the same direction, and to contrive means by which the intervals of intermission shall succeed each other so rapidly that the current shall have practically all the effects of a current absolutely continuous.

A powerful compound horse-shoe magnet, A, is firmly attached by bolts and screws upon a horizontal bed, beyond the edge of which its poles *a* and *b* extend. Under these is fixed an electro-magnet X Y, with its legs vertical, and mounted so as to revolve upon a vertical axis. The covered wire is coiled in great quantity on the legs X Y, the direction of the coils being reversed in passing from one leg to the other.

The two extremities of the wire proceeding from the legs X and Y are pressed by springs against the surfaces of two rollers, *c* and *d*, fixed upon the axis of the electro-magnet. These rollers themselves are in metallic connection with a pair of handles P and N, to which the current evolved in the wire of the electro-magnet X Y will thus be conducted.

If the electro-magnet X Y be now put in rotation by the handle *m*, the handles P and N being connected by any continuous conductor, a system of intermitting and alternately contrary currents will be produced in the wire and in the conductor by which the handles P and N are connected. But if the rollers *c* and *d* are so contrived that the contact of the ends of the wire with them shall be only maintained during a semi-revolution in which the intermitting currents have a common direction, or so that the direction during the other semi-revolution shall be reversed, then the current transmitted through the conductor connecting the handles P and N will be intermitting, but not contrary; and by increasing the velocity of rotation of the electro-magnet X Y, the intervals of intermission may be made to succeed each other with indefinite celerity, and the current will thus acquire all the character of a continuous current.

The forms of commutators by which the rollers *c* and *d* are made to break the contact, and re-establish it with the necessary regularity and certainty, or to reverse it during the alternate semi-revolutions are various.

166. All the usual effects of voltaic currents may be produced

with this apparatus. If the handles P and N be held in the hands, the arms and body become the conductor through which the current passes from P to N. If X Y be made to revolve, shocks are felt, which become insupportable when the current has a certain intensity.

If it be desired to give local shocks to certain parts of the body, the hands of the operator, protected by non-conducting gloves, direct the knobs at the ends of the handles to the parts of the body between which it is desired to produce the voltaic shock.

167. For telegraphic purposes it will be sufficient to place the line wire in connection with one of the handles P or N, while the other handle is in connection with the earth. A current will then be transmitted on the line wire which will be intermitting, but which may be rendered continuous by a combination of magneto-electric machines.

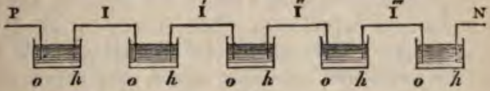
168. It remains, in fine, to show how the chemical properties of the electric current can be made to supply the means of transmitting signals between two distant stations.

When a current of adequate intensity is made to pass through certain chemical compounds it is found that these are decomposed, one of their constituents being carried away in the direction of the current, and the other in the contrary direction.

169. One of the most striking examples of the application of this principle is presented in the case of water, which, as is well known, is a compound of the gases called oxygen and hydrogen.

Let us suppose that a series of cups, *oh*, fig. 65, containing water are placed so that an electric current shall pass successively through them, commencing at the wire P and passing at *o* into the first

Fig. 65.



cup; thence through the water to *h*, and from *h* along the wire I to *o* in the second cup; thence in like manner through the water to *h*, and then along the wire I, and so on to N, the wire P being supposed to be connected with the positive pole of a battery, and the wire N with its negative pole. The current will therefore flow from P to N passing through the water in each of the cups. Under such circumstances the water will be gradually decomposed in each of the cups the particles of oxygen moving against the

course of the current, and those of hydrogen moving with it, the former are evolved at the points *o*, and the latter at the points *h*.

170. To show how this property of the current may be made to produce visible marks or signs, let us suppose a sheet of paper wetted with an acidulated solution of ferro-prussiate of potash to be laid upon a plate of metal, and let the point of a metallic style be applied to it so as to press it gently against the metallic plate without piercing it. Let the style be now put in metallic connection with the wire which leads to the positive pole of a voltaic battery, and let the metallic plate upon which the paper is laid be put in connection with the wire which leads to the negative pole. The current will, therefore, flow from the style through the moistened paper to the metallic plate, and it will decompose the prussiate, one of the constituents of which deposited on the paper will mark it with a bluish spot.

If the paper be moved under the style while the current flows, this decomposition being continued under the point of the style a bluish line will be traced upon the paper.

If while the paper is thus moved uniformly under the style, the current is permitted to flow only during intervals long or short, the paper will be marked by lines long or short, according to the intervals during which the current flows; and, since no decomposition takes place during the suspension of the current, the paper then passes under the style without receiving any mark. If the current be permitted to flow only for an instant, the paper will be marked by a dot. The long or short lines and dots, thus traced upon the paper, will be separated one from another by spaces more or less wide according to the lengths of the intervals of suspension of the current.

It is evident that the same effects will be produced, whether the style be at rest and the paper moved under it as is here supposed, or the paper be at rest and the style moved over it.

171. The paper may be moved under the style by various and obvious mechanical expedients. Thus it may be coiled upon a cylinder or roller, which being kept in constant and uniform revolution by clock-work or other means, the paper would be carried continually under the style, and unrolled from the cylinder after receiving the marks. Or the cylinder covered with paper might, while it revolves, receive a slow motion in the direction of its axis, so that the course of the style upon it would be that of the thread of a screw or helix. The paper might be cut into the form of a large circular disc, and laid upon a metallic disc of equal magnitude, to which a motion of revolution round its centre in its own plane might be imparted by clock-work; while the style might receive a slow motion directed from the

centre of the disc towards its edge. In this case the style would trace a spiral curve upon the paper, winding round it continually, and at the same time retiring constantly but slowly from its centre towards its edge.

172. Whichever method might be adopted, the paper would be marked with a continuous succession of combinations of lines of varying lengths and dots, separated by spaces more or less wide. These marks depending altogether on the succession of intervals of suspension and transmission of the current, which intervals can be varied and combined at will by an operator supplied with the means of controlling the current which have been already explained, it will be easily conceived that an agent at s can trace upon paper placed at s″ in the manner here described such a succession of characters composed of lines and dots as he may desire; and that an operator at s″, being supplied with a key, may interpret these characters, and thus translate the communication into ordinary language.

It is also easy to conceive that the agent at s can stop the clockwork which moves the paper at s″ or set it going at will, in the same manner as he can ring a bell or discharge a cannon.

173. It has been already explained that the intensity of the current transmitted by a given voltaic battery along a wire of given thickness must decrease in the same proportion as the wire increases in length. This loss of intensity due to the length of the wire is increased in the practical operation of the telegraphs by the loss of electricity arising from imperfect insulation and other inevitable causes. It has therefore become a matter of great practical importance to discover expedients by which the intensity of the current may be re-established, or by which the apparatus may be worked by a very feeble current.

It was obvious that the intensity might be maintained at the necessary degree of force by providing, as already stated, relay batteries at intermediate stations sufficiently near each other to prevent the current from being unduly enfeebled. But the maintenance of such numerous batteries in cases where great distances must be traversed is expensive, and it was desirable to discover some more economical expedient.

174. The properties of the electro-magnet have supplied the means of accomplishing this.

The lever *g h* (fig. 58) may be constructed so light and so free, that it will be capable of being moved by a current of extremely feeble intensity. But if this lever were charged with any of the functions by which it would become an instrument for giving signals, such as the ringing of a bell or the motion of a style or pencil, it would be necessary to impart to the electro-magnet and

its other appendages much greater power. So long, however, as no more is required than to make it oscillate between the stops t and t', it may be constructed and mounted so as to be moved by the most feeble degree of magnetism imparted to m m' by a current of extremely low intensity.

Now let us suppose the axis o of the lever g h to be in metallic connection with a voltaic battery placed near to it at the station S', and let the stop t' be in connection with the conducting wire which extends to another more distant station S''. When the end g of the lever is brought into contact with the stop t', the current produced by the battery at S' will flow along the conducting wire to S''; and when the lever deserts the stop t', and is thrown upon t, the contact being broken, the current is suspended.

Now it is evident that by this means the original current flowing from the battery at the station S to the station S' is the means of calling into action another current, which flows from the relay battery at the station S' along the conducting wire to the station S'', and that the intensity of this current will not be affected in any way by that of the original current from S to S', but will depend solely on the power of the relay battery at S', and the length of the conducting wire from S' to S''.

In the same manner another relay battery may be provided at S'', and so on.

In this succession of independent currents, those only which have signals to work need to have a greater intensity than that which is sufficient to give motion to a light lever, such as we have described above.

It will be evident also by what has been stated that the pulsations given to the original current at S, and the succession of intervals of transmission and suspension will be reproduced with the most absolute precision in all the succeeding currents, so that all signals which depend on these intervals of transmission and suspension will be made at the final station as promptly and exactly as if the original current from S to S' had been continued throughout the entire line of communication with all the necessary intensity.

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175. The lines of electric telegraph which have been constructed and brought into operation in different parts of the world, like the lines of railway, have been established in some by private *companies*, and in others by the state. In the United Kingdom *and its* dependencies and in the United States they have been in *all cases* established by the enterprise and capital of joint-stock

companies chartered or incorporated by the legislature, subject to certain conditions. On the continent of Europe generally they have been constructed and are exclusively worked by the state, but are placed under specified conditions and subject to regulated tariffs at the service of the public.

176 The forms of telegraphic instruments to which a preference has been given, in different countries are very various. In the United Kingdom and the United States, the several joint-stock companies by whom telegraphic lines have been constructed, have been generally formed by the friends and partisans of the inventors of particular telegraphic instruments, of which the companies have become severally the patentees. To these instruments they naturally have given a preference, in some cases irrespective of their merits, and as a necessary consequence every such company is more or less opposed, as well by interest as by prejudice, to other inventions and improvements. It has been a matter of complaint that such companies have sometimes become the purchasers of patented inventions for no other purpose than that of their suppression; and it is easily conceivable that a company having an extensive establishment in profitable operation may find it more advantageous to maintain their existing apparatus than to put them aside for others even of very superior efficiency. This is, after all, no more than what has occurred in the progress of all great inventions and improvements.

177. National feeling has, however, also had a considerable influence on the selection of the forms of telegraph adopted in different countries. Thus we find the telegraphs adopted in England exclusively English inventions; those generally adopted in France, French inventions; and those adopted in the United States, generally American inventions.

178. Amidst those conflicting motives directing the choice of companies and of governments, several inventions of great merit have necessarily been either wholly neglected, or bought up and wilfully suppressed, or in fine, brought into operation on a very limited scale.

The vast resources supplied by the discoveries by which physical science has been enriched since the beginning of the present century, and the fertility of genius directed to the application of these resources in all countries, has produced a swarm of inventions, even the least efficient of which possess great merits on the score of ingenuity and address in the application of physical principles. Our limits, the purposes to which this series is directed, and the large and various classes to which it is addressed, compel us to pass without notice many forms of telegraph which have been contrived and constructed. We shall

therefore confine our observations to those apparatus which have been actually employed on the telegraphic lines established in different countries, and a very few others which appear to claim more especial attention.

On the claims of various projectors on the score of original invention, we must generally decline to enter. To discuss such questions so fully as to render justice to the claimants would require much more space than we can devote to the subject; and however interesting such a discussion might be to the inventors themselves and their partisans, it would offer but few attractions to the masses to whom our "Museum" is addressed.

We shall therefore first explain briefly the forms of telegraph generally applied in this country, and next those which are in operation elsewhere.

179. The telegraphic instruments used almost exclusively in this country are galvanometers (138), which make their signals by means of the deflections of magnetic needles, produced by the electric current.

These instruments are of two forms, the first, and most simple, consisting of one needle with its appendages and accessories, and the other of two independent needles, each accompanied by its own appendages.

THE SINGLE NEEDLE INSTRUMENT.

180. This instrument consists of a galvanometer and a commutator, mounted in a case resembling in form and size that of an ordinary table time-piece.

A front view of it is given in fig. 66 (vol. iii. p. 161). On the upper part is a dial, in the centre of which the indicating needle appears, like the hand of a clock, fixed upon an axis. Its play to the right and left is limited by two ivory studs inserted in the face of the dial, a short distance on each side of its upper arm.

The handle which works the commutator, also fixed upon an axis, is presented at the lower part of the case, under the dial.

Upon the dial are engraved the letters of the alphabet, the ten numerals, and one or two arbitrary symbols, under each of which is engraved a mark, indicating the motions of the needle, by which the letter or figure is expressed.

The galvanometer, constructed as already explained (140), is attached to the back of the dial, the axis of its magnetic needle passing through the dial and carrying the indicating needle in front.

The latter is also usually magnetic, its poles being reversed in their direction with relation to those of the interior needle, the

effect of which is, that the current transmitted through the galvanometer has a tendency to deflect both needles in the same direction. The indicating needle, however, need not be magnetic. If it be sufficiently light, being free from magnetism, it will be carried by the axis to the right or left against the studs, by the deflections of the galvanometric needle which plays within the coils of the galvanometer, to which it is always parallel.

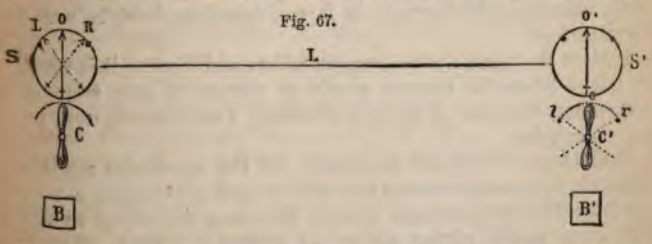
In connection with the instrument there are, as usual, an alarum and a galvanic battery.

By the commutator, the current produced by the battery may be transmitted upon the line-wire, or suspended or reversed in its direction, according to the position given to the handle. If the handle be vertical, as represented in the figure, the current is suspended, the arrangement of the commutator being then such as to cut off all communication between the battery and the line-wire. If the upper arm of the handle be turned to the right, the battery will be connected with the line-wire, on which accordingly the current will be transmitted. If the upper arm be turned to the left, the battery will still be connected with the line-wire, but with its poles reversed, so that the direction of the current on the line-wire will be reversed.

The mechanical form of the commutator, by which these changes of connection are made is different from that explained in (111), but the principle is the same, and the variation of the details are unimportant.

To comprehend the practical operation of the instrument, we are to consider that similar instruments, with similar accessories, are placed at each of the stations, between which dispatches are to be transmitted. To render the explanation more clear, let S and S′, fig. 67, be the two stations, O and O′ the dials, C and C′

Fig. 67.



the handles of the commutators, and B and B′ the galvanic batteries. If it be intended to send a dispatch from S′ to S, the arm *of the commutator,* C, is left in its vertical position, so that no *current can pass* from the battery, B, to the line-wire, L.

When the arm of C′ is vertical, no current can pass from B′ to L, and consequently the needle of O will remain in the vertical direction, without deflection. If the upper arm of C′ be turned to the right, *r*, the current from B′, passing along L, will flow through the coil of the galvanometer at S, and will deflect the indicating needle to the right, so that it will lean upon the right hand stud, R. If C′ be then turned back to the vertical direction, the current will be suspended, and the needle at S will return to the point O. If the upper arm of C′ be then turned to the left, *l*, the current will be again transmitted upon the line-wire, L, but in a direction contrary to its former course, and thus passing through the galvanometer at S, in a contrary direction, the needle, which was before deflected to the right hand stud, R, will now be deflected to the left hand stud, L.

Thus, it appears, that according as the upper arm of C′ is turned to the right or left, or placed in the vertical position, the needle on the dial at S, is also turned to the right or left, or placed in the vertical position.

In a word, whatever position is given to the handle of the commutator at S′, a corresponding position is assumed by the indicating needle at S, and these changes of position of the indicating needle at S, are absolutely simultaneous with the changes of position of the handle of the commutator at S′.

The manner of expressing the letters and figures, is by making repeated deflections of the needle right and left, making a short pause at the end of each letter signal. Thus two deflections to the left express A; three, B; four, C; while one expresses the completion of a word. One to the right expresses M; two, N; three, O; and four, P. In the same manner, L is expressed by four deflections, which are, successively, right, left, right, and left.

As these signs are purely arbitrary, and may be changed in every independent telegraph, it is not necessary here to notice them further.

Besides the signals which express letters and figures, it is usual to adopt others to express words or phrases of very frequent occurrence, such as, *I don't understand*, *I understand*, *wait*, *go on*, *repeat*, &c.

It is usual, though not necessary, for the agent who sends a dispatch, to pass the current through his own instrument, so that his indicating needle shows exactly the same deflections as the indicating needle of the station he addresses. Thus, when S′ addresses S, his own indicating needle, O′, speaks as well as the indicator, O, of the station, S.

All that has been stated in (111) *et seq.* of the transmission of the same despatch through a series of stations, of cutting off the

transmission from all stations except that to which it is exclusively addressed, of the use of the alarum, &c., is applicable, without any important modification to this form of telegraphic instrument.

THE DOUBLE NEEDLE TELEGRAPH.

181. This is nothing more than two single needle telegraphs, such as has been just explained, mounted in the same case, their indicating needles playing side by side upon the same dial, and the handles of their commutators placed so that they can be conveniently worked at the same time, by the right and left hand of the telegraphic agent. Each instrument is altogether independent of the other, having separate accessories, and transmitting its current upon a separate line-wire.

The purpose of this form of instrument is merely to accelerate the transmission of dispatches, by enabling the agent to produce the signals expressing letters and figures in more rapid succession. In the single instrument there are only *two* signs made by one deflection of the needles, viz., a deflection to the right and one to the left. In the double instrument there are *eight* such signs, viz., two with each needle, as in the single instrument, and four obtained by combining the deflections of the two needles. Thus, if 0 express the position of the needle without deflection, *r*, a right hand, and *l* a left hand deflection, and R the right hand, and L the left hand needle, the following eight signals may be made in the time of a single motion of either needle.

L	R
r	0
l	0
0	*r*
0	*l*
r	*r*
l	*l*
r	*l*
l	*r*

With a single needle two deflections can only make four signals, viz., *r r*, *l l*, *r l*, *l r*. But with two needles, these being combined

with single deflections and with each other, a greater number of different signals can be obtained than are sufficient to express the letters and numerals, each being made in the time necessary for two deflections of a single needle.

A front view of a double needle telegraph is given in fig. 68 (vol. iii. p. 177).

The small case at the top contains the alarum, and the small handle at the side of the large case is the commutator by which the current is turned on and off the alarum. The two large handles which appear in front are those of the commutators, which produce the changes of direction of the current, and when inclined to the right or left the needles acted on by the current assume a like position.

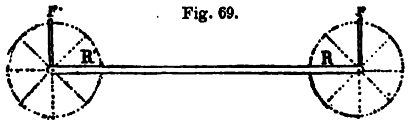
FRENCH STATE TELEGRAPH.

182. When the establishment of lines of electric telegraphs was proposed in France, the old aerial telegraph was, and had been for more than half a century, in operation, and formed a department in the public administration of considerable importance, employing an extensive body of agents, dispersed throughout the country, most of whom were specially instructed and qualified for the business.

The commission appointed by the government required that the electro-telegraphic instruments should exhibit the same signals as had been already used in the case of the former telegraph.

The old telegraph consisted of a long straight bar, R R′, fig. 69, called a regulator, to the extremities of which two shorter bars, r r′, called indicators, were attached by pins or pivots, so that each indicator was capable of turning on its pivot, so as to make any desired angle with the regulator.

Fig. 69.



If we suppose the circle described by each indicator to be divided into eight equal arcs of 45°, and that any convenient mechanism is provided, by which the agent who conveys the signals can at will give to each indicator any of these eight positions, each indicator would be capable of making eight signals, and by combining these in pairs, the two indicators worked together would be capable of giving sixty-four signals.

It is evident that even this large number of signals might be

further multiplied, by giving to the regulator itself a motion round its centre, so that it might at will assume the horizontal or vertical position, or might take an intermediate direction.

In transferring this system of signals to the electric telegraph, the regulator is supposed to be placed permanently horizontal, and the two indicators to be capable of receiving any of the eight positions here explained.

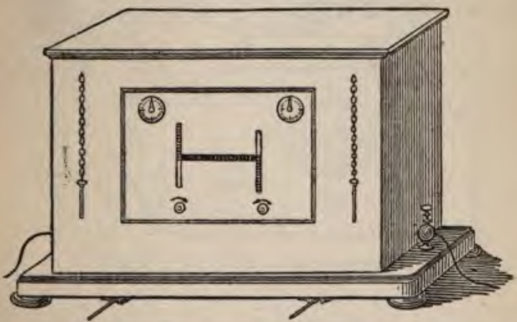
183. The telegraph contrived by M. Breguet, to exhibit such a system of signals, consists, like the double needle telegraph, of two distinct and perfectly similar instruments, one for each of the indicators. They are mounted side by side with their accessories in the same case, at a distance apart sufficient to allow the indicators to revolve without mutual obstruction, and sufficiently near each other to allow the same person to work both at the same time with his right and left hand.

Each instrument consists of an indicating apparatus and a commutator.

If s and s′ be two stations, between which dispatches are transmitted, the commutator at s moves the indicator at s′, and the commutator at s′ moves the indicator at s.

A view of the indicating apparatus is given in fig. 70. The two indicators are fixed upon axes placed in the same horizontal

Fig. 70.



line upon the dial. These axes, passing through the dial, carry behind it two escapement wheels, which are controlled by two anchors, as described in 151. These anchors are moved by the armatures of two electro-magnets, from which they receive vibrations, like those of a pendulum. The escapement wheels are *impelled by the force of* two main-springs, transmitted to them by *two similar trains of* clock-work.

Thus, for each swing of the anchor, the indicator makes one motion forward, and as the escapement wheels have each only four teeth at equal distances, one complete revolution of these wheels must cause the indicators to make a complete revolution by eight distinct motions, produced by the four swings of the anchor to the right, and the four swings to the left.

During a revolution of each of the escapement wheels, therefore, each of the indicators takes successively the eight positions required in the proposed system of signals, and since the motions of the indicators are governed by the anchors, those of the anchors by the armatures of the electro-magnets (154), and those of the electro-magnets by the successive pulsations of the electric current, it follows that if it can be contrived that commutators at one of the stations shall govern the pulsations of the current at the other, they will necessarily govern the motion of the indicators at that other station.

At the upper corners, right and left of the front of the case, are two dials, in the centre of which are axes, which act, when turned, upon the springs which draw back the armatures of the two electro-magnets, and near them keys for their adjustment are suspended by chains. The springs are raised or relaxed, according as the keys are turned in the one direction or the other.

Under the indicating arms are two axes with square ends, by which the two systems of clock-work can be wound up, which is done by the same keys.

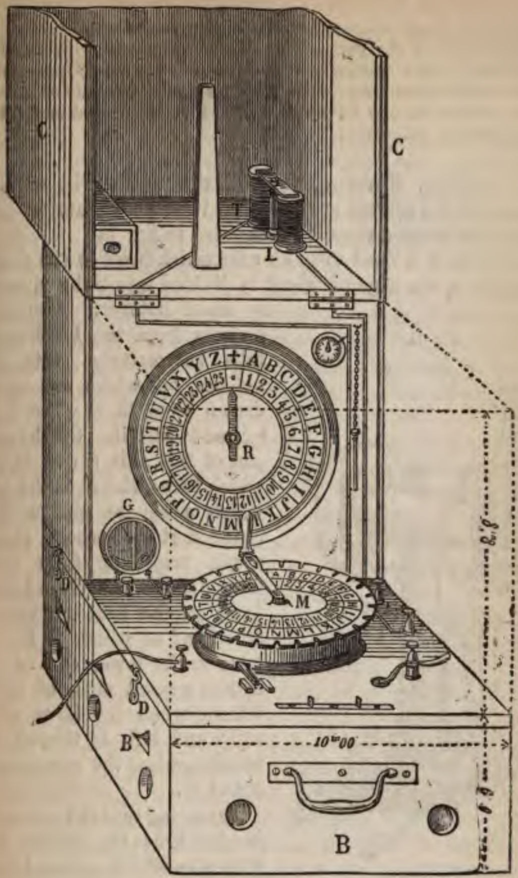


Fig. 74.—FRENCH RAILWAY TELEGRAPH.

THE ELECTRIC TELEGRAPH.

CHAPTER VIII.

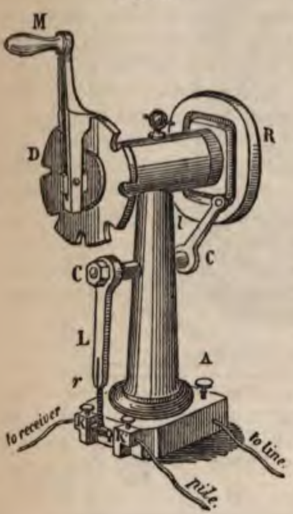
184. Form of commutator of French state telegraph.—185. Its operation.—186. Method of sending and receiving a despatch.—187. Batteries.—188. *French railway telegraph.*—189. French railway portable telegraph.—*190.* German railway telegraph.—191. Siemens' instrument.

184. It remains, therefore, to show the manner in which the pulsations of the current are governed by the commutator.

One of the commutators is represented in fig. 71.

The handle M is fixed upon an axis which turns in the centre of a fixed disc D, the edge of which is divided into eight equal parts by small notches. A short pin projects from the handle which falls successively into these notches, but which can be withdrawn from them when it is required to turn it. On the remote end of this axis a disc is fixed, which turns with it, in the face of which a square groove is cut, rounded at the corners, in which a pin projecting from a short lever l is moved. This lever l is fixed on the axis C C, upon the other end of which is fixed the lever L, the lower end of which carries a small piece of metal r, which, when the lever vibrates right and left, is thrown alternately against the contact-pieces K and K′.

Fig. 71.



Supposing that the commutator is placed at the station S, the line-wire which comes from the station S′ enters the foot, and is held there by a tightening screw A. This wire is in metallic connection, through the pillar, with the lever L, and consequently with the piece of metal at its lower end, which oscillates between the contact-pieces K and K′. This piece of metal, r, may therefore be considered as virtually the extremity of the conducting wire between the stations S and S′.

Attached in like manner, by tightening-screws, to the two contact-pieces K and K′ are two wires, one of which is connected with the battery, and the other with one end of the coil-wire of the electro-magnet, in the indicating instrument of the station S.

The other end of this coil-wire is either connected with the line-wire which proceeds to the succeeding station, or with the earth, at the option of the agent, a commutator being provided by which this change of direction may be made.

185. Let us see, then, in what manner the agent at S, provided with such a commutator, can govern the motion of an indicator at S′.

The arrangement of the apparatus is such, that when the handle M of the commutator is presented vertically upwards, as represented in the figure, the pin being in the highest notch, the lever L presses against the contact-piece K.

Let the highest notch be supposed to be numbered 1, and the others proceeding round the disc, in the direction of the motion of the hand of a clock, be numbered successively 2, 3, 4, 5, 6, 7, and 8.

It must be remembered, that at the other station, S′, there is another commutator precisely similar, the corresponding points of which we shall express by the letters M′, D′, R′, &c.

Let us see, then, how the agent at S, by moving round the handle M from notch to notch, can govern the motion of the indicator at S′.

The commutator and indicator at the station S′, when not employed in the transmission of a despatch, are placed respectively with the arm M′, having its pin in the notch 1′, and the hand of the indicator directed vertically upwards.

186. The arm M being, as represented in the figure, in the notch 1, let it be moved to the notch 2. The lever L being moved to the right, the piece r will be thrown upon K′. Being then in connection with the battery-wire, the current will pass by r and L to A, and thence by the line-wire to the corresponding point A′ of the commutator at the station S′, and thence through the pillar to the lever L′ and the piece r'. But since, as has been just explained, M′ is in the notch 1′, the piece r' must rest against K. The current, therefore, arriving at this point, will pass from K by the wire to the coil of the electro-magnet at S′, to which it will impart magnetism, so that it will attract the armature, and move the anchor of the escapement, so as to make the indicator move from the vertical position 45° in the direction of the hand of a clock.

If the handle M be now moved from notch 2 to notch 3, the lever L will be thrown back to K, and the contact with K′ being broken, the current will be suspended, and the electro-magnet at S′ losing its power, the armature will recoil from it by the action of the spring (147) and the anchor of the escapement being again moved, the indicator will be advanced through another angle of 45°, *and will be then in the horizontal position pointing to the right.*

In like manner, it may be shown that when the arm M is moved from the notch 3 to the notch 4, the indicator at S′ will be moved from the horizontal position to one which will make an angle of 135°, with its original direction, or what is the same, 45°, with the position in which it would point directly downwards.

Without pursuing this explanation further, it will be easy to see that the successive positions assumed by the hand of the indicator at S′ correspond with those given to the arm M of the commutator at S.

We have here explained the action of one commutator at S upon one indicator at S′. The action of the other commutator at S upon the other indicator at S′ is precisely the same. It must be understood, that the two commutators at S are connected with separate and independent line-wires, are supplied with separate and independent batteries, and act upon separate and independent indicators at S′. The right-hand commutator at S is connected with the right-hand indicator at S′, and the left-hand commutator with the left-hand indicator.

From what has been explained, the process necessary, as well for receiving as for transmitting a despatch will be understood. In the reception of a despatch, the agent has only to place the handle of his commutator in notch 1, and to see that his indicator is vertical. After that he has only to observe the successive attitudes assumed by the two indicators upon the dial before him, and to write down the letters they successively express.

Since this form of telegraph gives 64 signs, while 26 are sufficient for the alphabet, and 10 for the numerals, there are 24 signs disposable for abridgements, such as syllables, words, and phrases of most frequent occurrence.

187. The battery employed in working these telegraphs is at present invariably that of Daniel (32). Formerly Bunsen's battery (34) was used at chief stations, where great power is often required, but this has now been discontinued.

Between the point K′ and the battery a commutator is placed, by means of which the agent can bring into action a greater or less number of the pairs composing the battery, so as to proportion the power to the distance to which the current is to be transmitted, or to the resistance it may have to overcome.

A perspective view of the telegraphic instrument, showing the two indicators and two commutators, in their respective positions, is given in fig. 72 (vol. iii. p. 193).

FRENCH RAILWAY TELEGRAPH.

188. The telegraphs which convey letters or words by conventional signals, like those described above, require a staff of agents

ngaged in their management, who have been specially instructed nd practised, as well in working the instruments as in interpreting heir signs. That this is deemed a matter of great practical nportance in telegraphic economy is manifested by the fact lready mentioned, that the French government, before it resolved o establish the electric telegraph, caused instruments, on the new rinciple, to be constructed, by which the same system of symbols ould be used as that which had been previously adopted in the emaphore.

Nevertheless, in cases like that of a system of telegraphs in which not only the business of the state, but that of the public, is o be transacted, and where, therefore, a permanent staff is mployed exclusively in the management of the apparatus, no very serious difficulty can be encountered, even if the necessity of having a new telegraphic vocabulary is imposed upon these agents.

For a short time the service will be slow, and less satisfactory, but the inconvenience is temporary, and constant practice in the manipulation of the apparatus, and in the interpretation of the signs, whatever they may be, renders the agents sufficiently expert.

The case is different with telegraphs used, not for state or commercial purposes, but exclusively for railway business. The telegraphs even of principal railway stations, and still less those of secondary stations, are not in that constant requisition, and consequently do not occupy a permanent and exclusive class of agents. They are managed by any persons who happen to be employed in the respective offices: by the station-masters, clerks, railway police, guards, or, in short, by any railway agent who may happen to be at hand. Now it is evident that telegraphic instruments, the use of which would require special instructions, and much previous practice, would not answer such a purpose.

These considerations have prevailed, with the administrations of the lines of railway in all parts of the continent, and have led them to adopt telegraphic instruments which satisfy the conditions explained above, more completely than do the apparatus which have been adopted for state and public communications.

In general the railway telegraphs are of the class called "letter or alphabetic telegraphs." The agent who transmits a message is supplied with a hand which moves upon a dial, round which the letters of the alphabet are engraved, as are the hours round the dial of a clock. At the station to which the message is sent, there is a similar dial, having upon it a similar hand, and the mechanism is so contrived that, when properly adjusted, the two hands must always point to the same letter. Thus, if the agent sending the message turns the hand to the letter M upon the dial before him,

the hand upon the dial at the station to which the message is sent will also turn to the letter M, and in this way, by merely directing the hand successively to the letters of a word, pausing a little while at each letter the word will be spelled to the agent at the distant station.

All alphabetic telegraphs, whatever be their form or construction, convey the communications in this manner.

The French railway telegraph is in its principle identical with the state telegraph. The indicator in the latter makes a complete revolution by eight successive steps, moving in each step through an angle of 45°. If the alphabet consisted of only eight letters, this would at once become an alphabetic telegraph by fixing the indicator in the centre of a dial upon which, at equal distances asunder, the eight letters are engraved. But since the French alphabet consists of 25 letters, and since an additional sign is found convenient, the dial is divided into 26 equal arcs instead of eight, and the indicator makes a complete revolution by 26 equal motions, at the termination of these motions respectively pointing to the letters engraved upon the dial.

To accomplish this, the escapement wheel is constructed with 13 teeth instead of 4, the groove upon the moveable disc of the commutator has 13 sinuous undulations instead of 4 sides with rounded corners, and the fixed disc upon which the handle of the commutator moves, has 26 notches instead of 8.

The grooved disc, by the motion of which the oscillations right and left are imparted to the lever which makes and breaks the connection with the battery, is fixed immediately behind the notched disc, and the sinuous groove has the form represented in fig. 51, and acts upon the lever in the manner described in 133.

The commutator, with its appendages, is represented in fig. 73. The fixed disc has at its edge 26 notches, into which the pin projecting from the handle falls, as in the state telegraph. Engraved upon the face of the disc are, on the outside, the numbers from 0 to 25, and on the inside the 25 letters (W being omitted, not being generally used in the French language), the 26th place having the mark +.

A part of the dial is broken away, to disclose the face of the moveable disc, with the sinuous groove behind the fixed disc. The lever G is visible, with its pin in the groove, and the oscillation of the end of the lower arm H between the contact-pieces, P and P′, is exactly the same as that described in 133 and in 184.

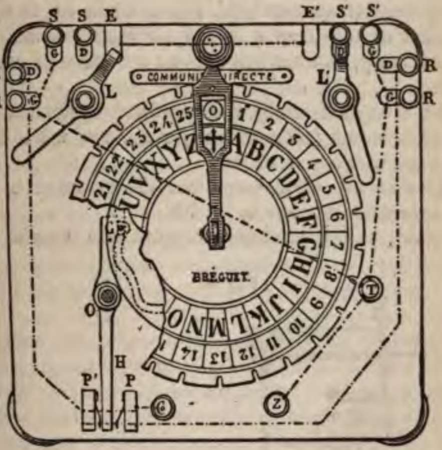
The handle of the commutator is keyed upon an axis which, passing through the centre of the fixed dial, is itself keyed into the centre of the moveable grooved dial behind it, so that when

the handle is carried round the fixed dial, the moveable dial behind is carried round with it.

Upon the upper part of the board carrying the dial are placed two supplementary commutators, L and L′, the hands of which play upon the contact-pieces, S, S, E, and S′, S′, E′, as well as upon an oblong plate of metal, upon which the words "COMMUNICATION DIRECTE" are engraved.

The terminals C and Z communicate with the copper and zinc ends of the battery, or what is the same, with its positive and

Fig. 73.



negative poles; T communicates with the earth. The contact pieces S S′ are connected with alarums, R R with the indicators, and the axes of the arms L L′ with the line-wires. The dotted lines indicate the positions of slips of metal inlaid in the back of the frame, by which the several pieces are put in metallic connection one with another.

After the general explanation of the manner in which the course of the current is in all cases governed, it will not be necessary here to explain the application of these commutating apparatus, which are nothing more than particular applications of the general principle so fully developed in 111.

A perspective view of the commutator and indicating apparatus mounted in the same case, is given in fig. 74 (p. 17). The commutator is fixed upon a horizontal desk, that being the most convenient position for its easy and rapid manipulation. The

indicator, which corresponds with it in form, is placed like the dial of a clock in front of a vertical case.

If we suppose the commutator (fig. 73) at the station S, and the indicator at S′, the arm of the commutator and that of the indicator being upon the mark +, any motion of the former made in the direction of the hand of a clock, will produce a corresponding motion of the hand of the latter, so that whatever letter or number the one points to, the other will at the same time point to.

By this means the agent at S may spell word after word to the agent at S′.

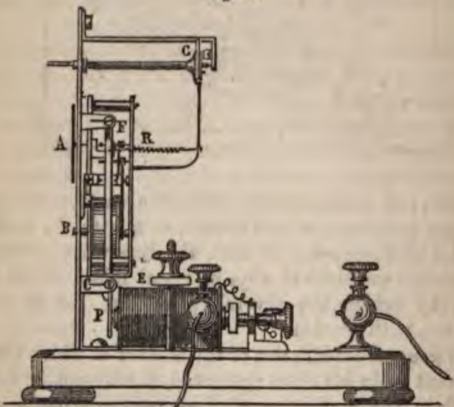
There are various conventional signs, made by two or more complete turns of the handle of the commutator, which, being altogether arbitrary, and matters of local convenience, need not be noticed here.

It is found that moderately well-practised hands can transmit with this instrument forty letters per minute, while the most expert can send as many as sixty.

A side view of the wheel-work and electro-magnet, E, of the indicating apparatus is given in fig. 75.

The armature, P, is alternately attracted and dismissed by the

Fig. 75.



magnet, acted on by the pulsations of the current, and imparts this motion to the escapement at F, by which the hand A of the indicator is advanced from letter to letter upon the dial, so that the motion of the hand A at the station S′ shall correspond exactly with that of the hand of the commutator at the station S.

189. The telegraph which is represented in fig. 74 is a portable telegraph constructed for the French railways by M. Breguet. This instrument, in size and arrangement, is adapted to be carried in the guard's van upon the train, so that, in case of accident, it may be immediately put in connection with the line-wires, and notice of the circumstance may be instantly transmitted to the two stations between which the accident has taken place.

Portable instruments for a like purpose have been constructed in England and elsewhere.

The apparatus consists of a stout oaken case, containing in the lower part, B B, a Daniel's battery of 18 pairs, a commutator, M, and an indicating apparatus, R. A small galvanometer is placed at G, to show the existence and force of the current, and a small electro-magnet, L T.

The dimensions of the instrument are indicated on the figure. When not in use the top, C C, attached by hinges to the case, can be turned down over the commutator and indicator, so as to close the entire apparatus.

A long rod of metal terminated in a copper hook, is provided, by which the end of the coil L can be put in connection with the line-wire; the end of the coil T being put in connection with the earth by means of a wire terminating in a small iron wedge, which is driven with a hammer into the joint between two of the rails.

To explain the manner of applying this apparatus, let us suppose an accident to happen between the stations S and S′, and consequently the train to be stopped. The guard takes out the portable telegraph, and raising its cover C C, he puts the wire of L in connection with the line-wire, and that of T within a joint of the rails, in the manner described above. He then makes one or two complete turns of the handle M of his commutator, observing whether the galvanometric needle G is deflected. If it is, he knows that he has transmitted a current to the line wires. This current divides itself at the hook, and a part goes to each of the stations S and S′, at each of which it rings the alarum. After a short interval a current is transmitted back from one or other of the stations, the arrival of which is indicated by the deflection of the galvanometric needle, G. The guard then informs the stations, one or both, of the accident, its place, the nature of the aid he requires, &c.

In comparing this with the state telegraph, it must not be forgotten that while this requires only one conducting wire, the state telegraph requires two. In fact, the French state telegraph, like the English double-needle telegraph, is in reality two independent telegraphs, whose signals are combined for the purpose of

obtaining greater celerity of communication by means of a greater variety of signals.

GERMAN RAILWAY TELEGRAPH.

190. The telegraphic apparatus used for the service of the Prussian railways, and for most of those of the German states, is one for which a patent was obtained by M. Siemens, of Berlin.

191. This apparatus consists of an indicating dial surrounded by the alphabet, upon which a hand moves, similar in form and external appearance to the indicating dial of the French railway telegraph already described (188), but placed upon a horizontal table instead of being vertical, as in the French telegraph. This dial is surrounded by a circular key-board, as shown in fig. 76, having as many keys like those of a piano-forte as there are characters upon the dial, the letter engraved upon each key being identical with that with which it corresponds in position upon the dial.

192. A lever, *a b*, is placed upon the table, turning upon the centre *b*, and limited in its play by two stops, T and R. When it is turned against T, the line-wire is put in connection with the indicating apparatus, and when it is turned against R, that wire is put in connection with an alarum. A current, therefore, which is transmitted along the line-wire can be made to pass through the indicating apparatus or through the alarum at will, by giving to the lever *a b* the one position or the other.

The usual means are also provided by which the current may be allowed to pass the station without going through either the alarum or the indicating apparatus, or by which it may be stopped at the station and turned into the earth. In fine, all the provisions common to telegraphs in general, which have been explained in 112, *et seq.*, are provided.

When no current passes upon the line-wire, and the instruments are not in operation, the lever *a b* at each station along the line is placed against R, so that the line-wire is everywhere in connection with the alarum.

If it be desired to transmit a despatch from any station, S, the agent at that station puts the line-wire in connection with the poles of his battery, so that a current may be transmitted to all the stations upon the line. This current rings all the alarums, inasmuch as the arms *a b* are placed against R at all the stations. The agents at the stations being thus called, remove the arms, *a b*, of their several instruments, and place them against the stops, T, the agent at the station S doing the same.

Previously to this, when the instruments were in repose the

hands rotate as before, passing again simultaneously from letter to letter until they arrive at the second letter upon which the transmitting agent has put his finger, when they again stop, and so on.

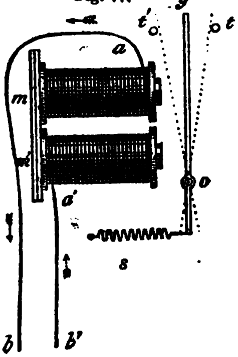
In this manner an agent at any station can stop the indicating needles at any or all the other stations successively, on their arrival at the letters of the words he desires to communicate.

193. If by reason of inattention or otherwise any letter or letters transmitted escape the attention of the agent at any of the stations to which the despatch is addressed, such agent immediately signifies the fact by putting his finger on one of the keys of his own instrument, by which he stops the hand upon the dial of the transmitting agent at a letter, which tells him to repeat the last letter or word as the case may be. This signal is understood at all the other stations, so that no confusion ensues.

194. Having thus shown how a despatch is transmitted and understood by those to whom it is addressed, I shall now explain the mechanism by which these effects are produced.

Beneath the dial of each instrument an electro-magnet, such as *m m′* (fig. 77) is placed, upon the coil of which the current transmitted from the batteries passes. This magnet, then, as usual, attracts its armature *g o*, which comes against the stop *t′*. Now the apparatus is so arranged, that when *g* strikes *t′*, the circuit of the current is broken, and consequently the current is stopped. This deprives the electro-magnet *m m′* of its magnetism; and *g* being no longer attracted, it is drawn back from the stop *t′* by the spring *s*, and it recoils upon the stop *t*. Here the connection with the line-wire is reproduced, and the current is re-established. The electro-magnet having thus recovered its magnetism, *g* is again attracted by it, and drawn into contact with *t′*, where the connexion is again broken, and *g* is drawn back to *t′* by the spring *s*, and so on.

Fig. 77.



Since the intervals of transmission and suspension of the current are the same throughout the entire line, and since the intervals of transmission are those in which the armature moves towards the electro-magnet, and the intervals of suspension those in which it recoils from the magnet, it follows that the oscillations of the armature of all the electro-magnets at all the stations are absolutely alike and simultaneous.

In each instrument the armature is in connection with a toothed wheel, upon the axis of which the hand *m n* (fig. 76) is keyed, so that each vibration of the armature puts forward one tooth of the wheel, and advances the hand *n* from one letter to another.

195. Upon comparing this arrangement with that of the French telegraph, it will be perceived that here the mainspring and wheel-work which moves the indicator are altogether omitted, and the armature of the electro-magnet, which in the French instrument only *regulates* the motion of the indicator, here both *moves* and *regulates* it. In fine, the armature here discharges at once the functions of the mainspring, and of the pendulum of a clock.

It will also be observed that the manipulation of the transmitting agent, by which he moves the indicators on the dials of the distant stations, is dispensed with, the current itself, through the intervention of the armature of the electro-magnet, imparting to the indicator a constant motion of rotation without any manipulation whatever.

That part only of the manipulation by which the indicator is stopped for a moment successively at the letters of the word intended to be transmitted, is retained, and that is effected by the action of the keys surrounding the dial.

196. Under the dial, a radius or arm is keyed upon the axis on which the indicating hand is fixed, so as to be always immediately under that hand and parallel to it, revolving simultaneously with it. This radius is a little longer than the indicating hand, and extends under the keys surrounding the dial. From the under-surface of each key a pin projects, the length of which is such that when the key is not pressed down, the radius passes freely under it; but when the key is pressed down, the pin comes in the way of the radius, and stops it when the indicating hand *n* arrives at the letter engraved on the key. By the action of the same pin the armature *o g* (fig. 77) of the electro-magnet is arrested in its return from *t′* to *t*, so as to be prevented from arriving at *t*. The current, therefore, is prevented from being re-established on the line-wire, as it would be if *g o* were permitted to come into contact with *t*.

Thus it will be understood how by putting down a key the two desired effects are produced. 1st, the stoppage of the indicating needles at the letter engraved on the key of the indicator on which such key is put down; and 2nd, the simultaneous suspension of the current along the entire telegraphic line, by which the indicating needles of all other instruments are stopped at the same letter.

197. This apparatus, compared with the French telegraph, to which it has an obvious analogy, has the advantage of greater *simplicity*. By dispensing with the mainspring and its necessary

train of wheel-work, and with the rather complicated commutator worked by the hand of the transmitting agent, many moving parts are rejected, and there are proportionately less chances of derangement and less causes of wear or fracture. But on the other hand the moving power which impels the indicator, being transferred from the mainspring to the current, a proportionately greater force of current is necessary. This force is, however, obtained without augmenting the magnitude of the batteries at any one station by the expedient of bringing the piles of both the terminal stations, and, if necessary, of any or all the intermediate stations, into the circuit.

198. In the batteries used with the French railway telegraph, the use of acid, as has been stated, is found altogether unnecessary. In the German telegraph, however, pure water does not give a sufficiently strong current, and it is acidulated with about one and a half per cent. of sulphuric acid. The battery at each station consists usually of from 15 to 20 pairs. The usual speed imparted to the indicator by the current is about 30 revolutions per minute.

M. Siemens invented mechanism by which the indicating apparatus was connected with one by which the letters of the despatch as they arrived were printed by ordinary type upon a band of paper. Since, however, this has not been brought into practical use, it will not be necessary to explain it.

When the electric telegraph was first opened to the general service of the public in Prussia, this apparatus of Siemens was generally used, but it has since been superseded by that of Morse, its speed of transmission being found insufficient for the public service.

BELGIAN RAILWAY TELEGRAPH.

199. When the electric telegraph was first brought into use on the Belgian railways, the French and German apparatus described above were tried in succession. In 1851 they were, however, both superseded by a form of telegraph invented and constructed by M. Lippens, mathematical instrument maker of Brussels.

200. M. Lippens attributes to the French and German railway telegraphs certain defects, which he claims to have removed. For the efficient performance of those telegraphs, it is evident that a certain relation must always be maintained between the force of the spring *s* (fig. 77), which produces the recoil of the armature *g o*, and the attractive force of the magnet, or what is the same, between the spring and the intensity of the current, with which the attraction of the magnet must vary. Now the intensity of the current is subject to variation, depending on the state of the battery, the number of pairs which are brought into operation, the length of

the line-wire upon which it is transmitted, the more or less perfect state of the insulators, and in fine on the weather.

If the current become so feeble that the attraction of the magnet is less than the force of the spring *s*, the armature *g o* will remain upon the stop *t*, from which the magnet is too feeble to remove it. If, on the other hand, the spring have not sufficient force to overcome the friction and inertia of the armature *g o*, and the small portion of magnetism which may be retained by the electro-magnet after the current has been suspended, the armature will remain upon the stop *t'*, the spring being unable to produce its recoil.

Since therefore the forces against which the spring *s* acts, and which it ought to exceed, and those which act against it and which ought to exceed it, are variable, it is clear that the maintenance of the efficiency of the apparatus requires that the spring *s* shall from time to time be adjusted, so as to be kept in that relation to its antagonistic forces, which are necessary for the due performance of the telegraph.

It has been already shown that very sufficient and very simple means of adjustment for this purpose have been supplied in the French telegraphs. The hands which appear in the upper corners of the instrument (fig. 70) are intended for this purpose, and being turned by the key, the springs connected with them are increased or diminished in their force, according as the key applied to them is turned the one way or the other. Similar adjustments are provided in the German instruments.

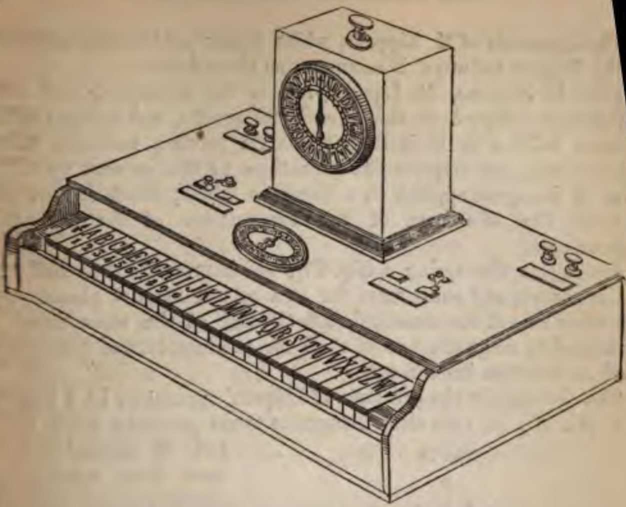


Fig. 81.—FROMENT'S ALPHABETICAL TELEGRAPH.

THE ELECTRIC TELEGRAPH.

CHAPTER IX.

201. Defects of the French and German instrument removed by Lippens' instrument.—202. Description of it.—203. Its wheel commutator.—204. Transmission of despatches by it.—205. Froment's alphabetic telegraph.—206. Morse's telegraph.—207. Froment's writing telegraph.—208. Bain's chemical telegraph.—209. Method of writing.—210. Electro-chemical pen.—211. Metallic desk.

201. M. Lippens and the Belgian railway and telegraph authori-ies by whom he has been supported, however contend, that lthough the permanent staff of the state and public telegraphs nstantly occupied and practised in the manipulation of such pparatus may be relied upon for the due management of such justments, the agents of various grades employed on the rail-ys, whose duties do not permanently connect them with the graph, and who are only called to it from time to time, cannot depended on to perform adjustments requiring not only con-t practice, but some address and some special knowledge of *rinciple and mechanism* of the apparatus.

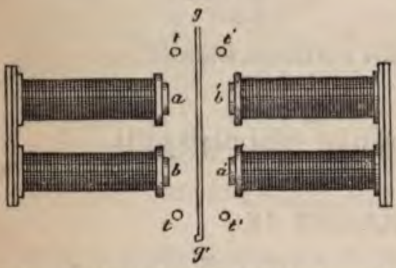
The apparatus of M. Lippens, which is now used for the service of the Belgian railways, is exempt from these defects.

Like M. Siemens, M. Lippens rejects the mainspring and its appendages adopted in the French telegraphs, and charges the current itself with their functions. He retains, however, the commutator, and imparts the pulsations to the current by the hand of the agent applied to a lever or winch, which is moved exactly like the arm of the commutator of the French instruments.

He rejects the spring *s* (fig. 77), which produces the recoil of the armature, and substitutes for it a second magnet placed on the other side of the armature, substituting at the same time a permanently magnetic bar of steel for the armature of soft iron used in the other instruments.

202. To explain the principle of Lippens' apparatus, let *a b* and *a′ b′* (fig. 78) be two electro-magnets made precisely alike, the coil of covered wire upon them being one continuous wire carried from one to the other, and rolled in such a manner that their polarity shall always have contrary positions in whichever direction the current may be transmitted on the wire. Thus, if *a* be a north pole, *b′* opposed to it will be a south pole, and in that case *a′* will be a north and *b* a south pole. If the current upon the coil be reversed, all these four poles will at once change their names—*a* becoming a south and *b′* a north pole, and *a′* a south and *b* a north pole.

Fig. 78.



Let *g g′* be a steel bar which is permanently magnetised, *g* being its north and *g′* its south pole, and let it be supported midway between the electro-magnets, having free play towards the one or the other until it encounters the stops *t t* or *t′ t′* by which it is arrested.

Now let a current be transmitted upon the wire, by which *a* will become a north pole, and consequently *b* and *b′* will be south poles, and *a′* a north pole. Since *g* is a north and *g′* a south pole, they will be attracted by *b′* and *a′*, and repelled by *a* and *b*, and consequently the armature *g g′* will be moved towards *b′ a′* until it is stopped by *t′ t′*. If the current be then reversed, *a* and *a′* will become south, and *b* and *b′* north poles; and the armature

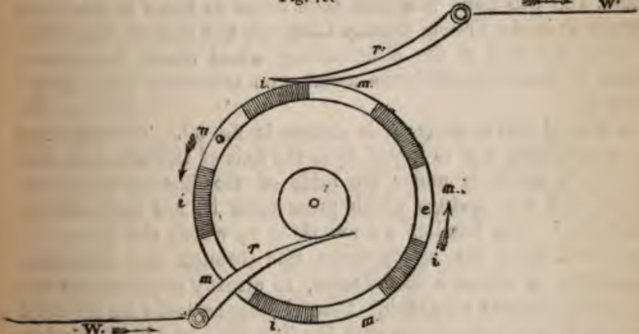
will be attracted by a and b, and repelled by b' and a', and will accordingly move towards the latter until it is stopped by $t\,t$.

If the direction of the current be reversed rapidly, suppose, for example, ten times per second, the armature $g\,g'$ will be made to oscillate ten times per second between the stops $t\,t$ and $t'\,t'$.

It is evident that the expedient adopted by Siemens, by which the transmission of the current is arrested by the contact of the armature with one stop and re-established by its contact with the other, might be easily modified so as to reverse the direction of the current by each contact with $t\,t$ and $t'\,t'$; and in that case the telegraph of Siemens would without other change be rendered exempt from the defects imputed to it, as well as the French instruments, by Lippens. But M. Lippens, either prevented from adopting this obvious expedient by the patent of Siemens, or giving a preference to the hand commutator for other reasons, has contrived an ingenious commutator worked by hand, by which he reverses the current with the greatest facility, rapidity, and precision.

203. This is a wheel commutator formed on the principle explained in 129, but there are two wheels such as are there described placed one upon the other upon a common axle, with a disc of gutta percha between them, so that one is insulated from the

Fig. 79.



other. The edges of both are divided into a series of conducting and non-conducting arcs, but the position of these relatively to each other is alternate, the conducting arcs of each disc corresponding in position with the non-conducting arcs of the other.

We may imagine the shaded arcs of fig. 79 to represent the conducting arcs of the upper, and the white arcs the conducting arcs of the lower disc, the one, however being separated from all contact with *the other by the* interposed disc of gutta percha.

When the wheel is made to revolve, the spring r' comes alternately into contact with the conducting arcs of the one and of the other disc. Another similar spring is applied to another part of the edge of the wheel, so as to be in contact with the conducting arcs of the upper disc, while the spring r' is in contact with those of the lower, and *vice versâ*.

One of the two discs is in connection with the copper, and the other with the zinc end of the battery, so that one may be considered as its positive and the other as its negative pole. One of the springs is in connection with one end, and the other with the other end of the conducting wire, which forms the coils, and which passes along the telegraphic line. By causing the wheel to revolve, therefore, the conducting wire will be alternately connected with contrary poles of the battery, and the current upon it will be reversed.

If the edge of the wheel be divided into ten equal parts by the conducting arcs, this reversion will take place ten times in each revolution, and if a revolution be imparted to the wheel in each second, the current will be reversed ten times per second.

In the apparatus of Lippens the oscillations thus imparted to the armature, $g\,g'$, fig. 78, are made to act by the intervention of toothed wheels upon the indicating hand which moves upon the dial around which the letters are engraved, as in the French telegraph, and this hand is moved from letter to letter in the same manner as in the French railway telegraph and that of Siemens.

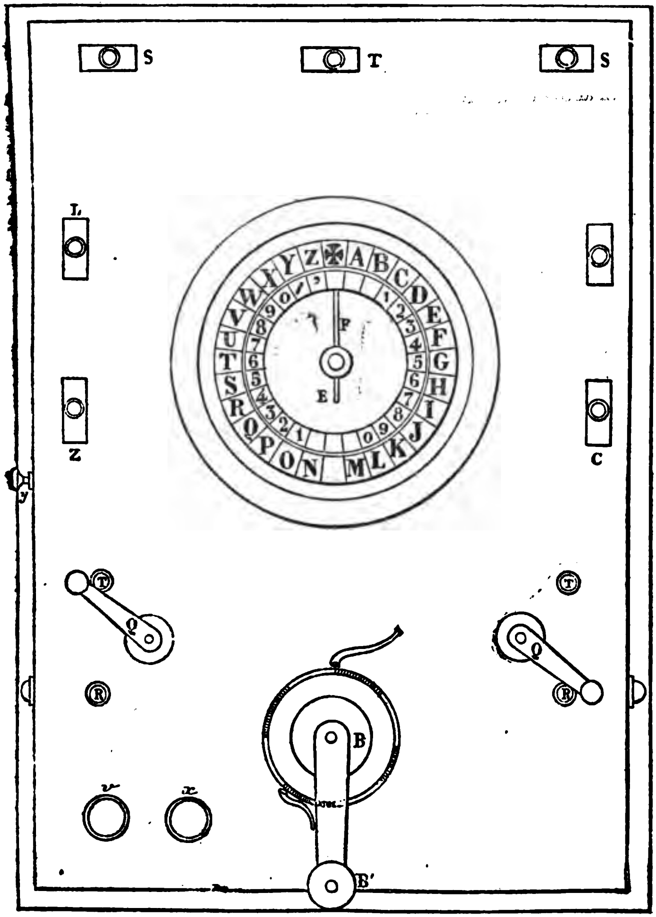
Upon the axle of the commutating wheel above described a winch is fixed by which the agent who transmits the despatch turns it.

A plan of this instrument is drawn in fig. 80. The handle of the commutator B B′ is keyed upon the axis of the wheel already described, which is under the table of the instrument. This wheel, and the springs which press upon it, are indicated in the figure. The handles Q Q are those by which the current is conducted from the up or down line through the indicating apparatus, or through the alarum, as already explained in the case of the German telegraph. Several other batteries are provided for establishing connections with the line wires, the battery poles, the alarums, and the earth, and differ in nothing essential from similar adjustments in other telegraphic instruments.

204. When the agent at any station, S, desires to transmit a despatch to any other station or stations, S′, he first, as in other telegraphs, calls the attention of the agents at S′ by means of the alarum. The current being then directed through the instruments severally by means of the adjustments provided for that purpose, the transmitting agent at S turns the handle B B′ of his

commutator, by which he produces the pulsations of the current, and puts the indicating hands upon the dials at s′, as well as upon his own in motion. These hands as usual, when properly

Fig. 80.



adjusted always point to the same letters. The transmitting agent stops the handle B B′ when he sees the hand F upon his dial point successively to the letters which spell the word he

desires to transmit, and by continuing to operate thus, he transmits the entire despatch.

Such is the Belgian railway telegraph, and although it must be admitted that it supplies a certain improvement on the French telegraph, it ought also to be stated that the difficulty and inconvenience which M. Lippens claims to have removed, has not been found to offer any practical obstruction to the satisfactory performance of the French instruments.

It appears that M. Lippens has lately made considerable improvements in the practical details of his telegraph, by which its operation is rendered much more convenient. He has also substituted the magneto-electric for the voltaic current, and thus dispensed with the voltaic battery. This last improvement has not yet (July, 1854) been applied on the telegraphic lines, but will be in operation, probably, before these pages come into the hands of the reader.

FROMENT'S ALPHABET TELEGRAPH.

205. The external appearance of this instrument, represented in fig. 81 (p. 33), is that of a small piano-forte, having, however, no black keys. On each of the keys a letter of the alphabet is engraved, the first key being marked with a cross, and the last with an arrow. On the first ten keys are also engraved the numerals. This part of the apparatus is the commutator, by which the agent at the station where it is placed, is enabled to transmit signals to any distant station.

Upon it is placed the indicating apparatus, which is acted upon by the commutator of the apparatus at a distant station, and by which a despatch is received. This indicator is similar in form and in the manner of giving its signals to that of the French railway telegraph already described. The dial of the indicator is marked with the letters of the alphabet, and the cross and arrow corresponding with the characters engraved upon the keys of the commutators.

At the back of the case containing the indicating apparatus the alarum is attached, and commutators are placed upon the case by which this alarum can be put in connection at pleasure with the line-wire. As usual it is always kept in connection with it when the instrument is not in use, so that notice may be given of the approaching arrival of a despatch. On the ringing of the alarum the agent at the station turns off the commutator from the alarum and throws it into connection with the indicating apparatus.

To explain the tranmission of a despatch, let us suppose an apparatus, such as that represented in the figure, to be erected

at two stations, S and S′, connected as usual by a conducting wire; the instrument, being unemployed, the line-wire at both is in connection with the alarum. Now let us suppose that S desires to transmit a despatch to S′. In that case S having first turned on the current, puts down any key whatever of his commutator, the effect of which is that a current is transmitted upon the line wire to S′, which rings the alarum; then S′ replies by transmitting a return current in the same way to S, by which S's alarum is rung. All being then prepared for the transmission of the despatch, S puts down with his fingers successively the keys of his commutator upon which the successive letters spelling the words of the despatch are engraved, and simultaneously with this the indicator upon the dial of S′ points to the same letters, which are taken down by S′. At the end of each word, S puts down the key marked with the cross.

When it is intended to transmit numerals, S puts down the arrow just before he begins them, and the cross when he ends them. Thus if it be desired to transmit the number 1854, S first puts down the arrow, and then the keys marked A, H, E, and D successively, after which he again puts down the cross to indicate that the number is finished. It remains now to explain how these effects are produced.

Within the case, and at some distance below the key-board, a steel rod is extended, parallel to the line of keys, the length of which corresponds with that of the row of keys. From this rod, and at right angles to it, proceeds a series of short steel arms, one under each key. In the bottom of each key, and at right angles to it, is inserted a short projecting pin, which corresponds precisely in position with the short steel arm just mentioned. The length of the arm, and that of the pin, taken together, is a little less than the distance between the bottom of the key and the steel rod when the key is not put down by the finger, the necessary consequence of which is that in that position of the key the rod may revolve, carrying the arm round with it unobstructed. But when the key is put down by the finger, the bottom of it is brought to a distance from the rod which is less than the sum of the lengths of the projecting arm and the pin, and consequently if the rod revolves, carrying with it the projecting arm while the key is thus held down, the pin coming in the way of the arm arrests it, and stops the further revolution of the steel rod.

It is evident that if the projecting arms were all inserted in the steel rod at the same side, or to speak with still more precision, if their points of insertion lay in a line along the side of the rod *parallel to its axis*, the pins of all the keys would arrest the *revolution of the rod* in exactly the same position, and, as it

will presently appear, that the position in which the rod is stopped determines the signal transmitted, it would follow as a consequence that in such case all the keys would transmit the same signal, and the indicator at the station to which the dispatch is to be transmitted would always return to the same letter upon the dial.

To prevent this, and to vary the signal in the necessary manner, the projecting arms are inserted in the steel rod according to a spiral or heliacal line, surrounding it like the thread of a screw, so that if, for example, the rod be placed so that the first projecting arm corresponding to the key marked with the cross, points directly upwards, the fourteenth which corresponds to the key M, will point directly downwards, and the intermediate arms will point at angles more and more inclined from the upward direction, each being deflected from the upward direction more than the preceding one by the fourteenth part of the half circumference.

In like manner, in proceeding from the arm corresponding with the key M, which points downwards, each successive arm will be more and more deflected from the downward direction, each being more deflected from it than the preceding one by the fourteenth part of half the circumference.

Thus the twenty-eight projecting arms divide the circumference of the rod into twenty-eight equal parts, and consequently in a revolution of the rod, the arms come successively to the position in which they point upwards and in which they would encounter the pin projecting from the bottom of the key if that pin were thrown in their way by the key being pressed down by the finger.

It will be evident, therefore, that if from any cause the steel rod be made to revolve, its motion may be stopped at twenty-eight different points of its complete revolution by means of the depression of the twenty-eight keys. We shall now show how a motion of revolution is imparted to this rod.

To its right-hand extremity is fixed a ratchet-wheel, which is in connection with a train of clockwork, moved in the usual manner by a mainspring. This clockwork is contained within the case of the apparatus. If it be wound up, and if nothing obstructs its action, a motion of continuous rotation will be imparted to the ratchet-wheel, and by it to the steel rod, and this motion will be more or less rapid according to the force of the mainspring, and the adjustment of a fly which is connected with it. They are so adjusted as to cause the rod to revolve two or three times in a second. But in the teeth of the ratchet-wheel, a catch is inserted, which counteracts the mainspring and prevents the motion, which can only take place when this catch is withdrawn. A bar is suspended parallel to the keys, and under them, by a contrivance called in mechanics a parallel motion, by means

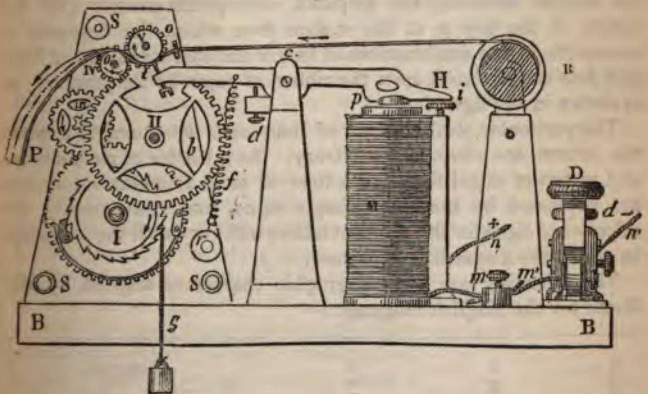
of which any of the keys when pressed by the finger will lower it. This bar rests upon the arm of the catch engaged in the teeth of the ratchet-wheel, so that whenever any key is put down by the finger, the bar is depressed, the catch disengaged, the wheel liberated, and a motion of revolution imparted.

On the left hand extremity of the steel rod is fixed a commutating wheel, similar in principle to that already described in the railway telegraph. This wheel, being fixed upon the rod, turns with it, moving when it moves, and stopping when it stops. Since the position in which the rod stops is determined by the key put down, the position in which the wheel thus fixed on the rod stops, is similarly determined. This wheel determines the pulsation of the current, and these pulsations determine the position of the indicator at the station to which the despatch is transmitted, in a manner which is substantially the same as that already described in the case of the railway telegraph.

MORSE'S TELEGRAPH.

206. This apparatus, which is applied on an extensive scale in America, and with some slight modifications in the Germanic States, is constructed upon the principle already explained in 153.

Fig. 82.



A general view of the instrument in its most usual form is given in fig. 82.

M is the electro-magnet; H is an armature working on the centre *c*; *i* an adjusting screw to limit the play of the armature, and *prevent its contact* with the electro-magnet at p; d another *adjusting screw to limit its* play in the other direction; t a metallic

style which marks by pressure a band or ribbon of paper drawn from the roll R, and carried between the rollers *o* and *o′*; P the ribbon of paper discharged from the rollers *o o′*, after being impressed by *t* with the telegraphic characters; I, *b*, &c., clockwork from which the rollers *o o′* receive their motion, by which motion the ribbon of paper is drawn from the roller R; *f* the spring which draws the arm H of the electro-magnet from the armature; S S the upright pieces supporting the clockwork; B B the base supporting the instrument; D, the key commutator, by which the current transmitted along the line-wire is alternately transmitted and suspended; *m*, *n*, *m′*, *n′*, wires by which the coil of the electro-magnet and the poles of the station battery are put in connection with the line-wires.

The general principle of this and all similar apparatus has been already so fully expained in 153, *et seq.*, that little more need be said here to render it intelligible. If it be desired to transmit a despatch to a distant station, the battery at the transmitting station is put in communication with the line-wire, and by the action of the key D the current is alternately transmitted and suspended during longer and shorter intervals, which are determined by the conventional telegraphic letters. The action of the style *t* against the ribbon of paper which passes over it at the station receiving the despatch, corresponds exactly with the action of the key D at the station from which the despatch is transmitted; and combinations of longer and shorter marks or lines and dots are produced upon the ribbon of paper by its pressure, as is shown in the figure.

The particular combinations of lines and dots used to express the letters are obviously arbitrary. As a matter of convenience and means of expedition, the letters of most frequent occurrence are expressed by the most simple signs, and consequently the selection of signs for the different letters will vary with the language in which the dispatch is expressed.

The following are the telegraphic characters adopted by Mr. Morse for the English language:—

							Numerals.				
A	·—	J	—·—·	S	···						
B	—···	K	—·—	T	—	1	·——·	9	—··—
C	·· ·	L	——	U	··—	2	··——··	0	———
D	—··	M	——	V	···—	3	···—·		
E	·	N	—·	W	·——	4	····—		
F	·—·	O	· ·	X	·—··	5	———		
G	——·	P	·····	Y	··—··	6	······		
H	····	Q	··—·	Z	··· ·	7	——··		
I	··	R	· ··	&	· ···	8	—····		

This telegraphic apparatus being that which has been by far the most extensively brought into use, being not only adopted almost exclusively in the United States and contiguous countries, but also in all the German States, it may be useful here to present the instrument and its appendages in the form in which it has been most recently constructed in the United States, and which has been recommended by the American telegraphic confederation, as being that which it would be most advantageous to adopt generally, so that all the parts being manufactured of the same pattern and size no difficulty would be found in replacing any of them in case of fracture.

A perspective view of the instrument, omitting the paper roller and ribbon, is given in fig. 83 (p. 44).

Z. The wooden base upon which the instrument is screwed.

B. The brass base plate attached to the wooden base Z.

A. The side frames supporting the mechanism.

h, *h*. Screws which secure the transverse bars connecting the side frames.

G. The key for winding up the drum containing the mainspring, or supporting the weight, according as the mechanism is impelled by one or the other power.

3, 4. Clock-work.

u. A lock or gauge to regulate the pressure of the rollers on the paper.

c. The pillar supporting the electro-magnet.

p. The adjusting screw passing into the pillar, *c*, projecting through the armature, to enable the telegraphist to adjust the sound of the back stroke of the armature at pleasure.

o. The spring bar, and

d, the screw to adjust the action of the pen lever.

D. The apparatus for adjusting the paper rollers.

f. The adjusting screw of the pen lever.

The form of the relay magnet recommended, is given in fig. 84 (p. 45), in its proper size.

A B, are the helices or coils.

C. The supporter of the magnet lightly screwed to

W, the connecting bar of the magnets.

T. Rosewood or ivory ends of magnets.

D. Armature screwed to

E, an upright lever;

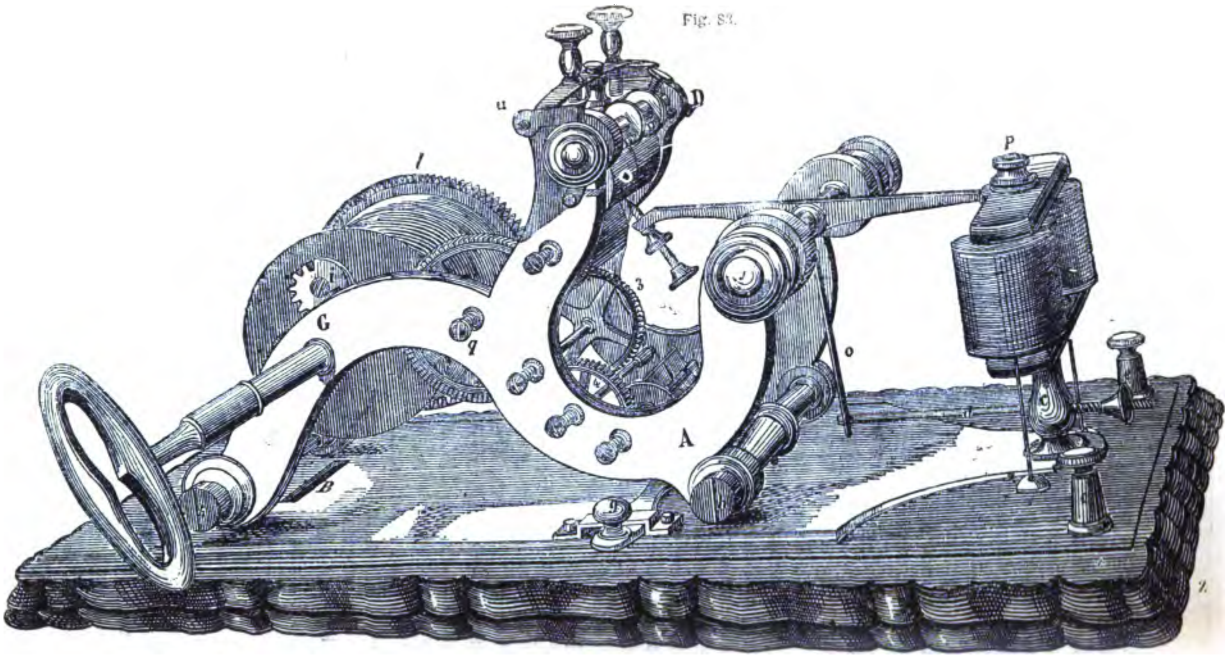
F, its axis, surrounded by a spiral spring, to perfect the connection in case of a fault at the ends of the axle.

M. The spring to produce the recoil of D and E.

L. Its adjusting screw.

H. An adjusting screw to limit the play of E towards the magnet-

Fig. 83.



R, its point of platinum.

S. An adjusting screw to limit the play of E from the magnet.

T. Its insulating point, in ivory.

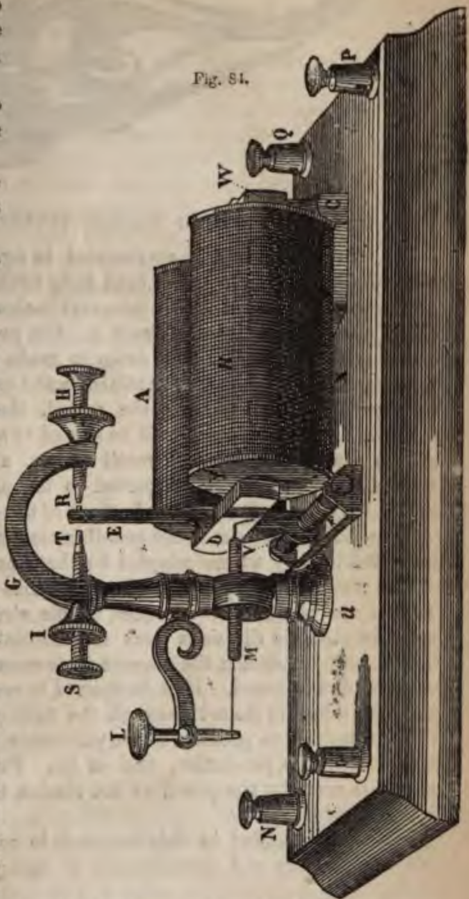
O N. Screws to connect with the wires of the station battery.

P Q. Screws to connect with the line wires.

X. The point where the coil wire passes through

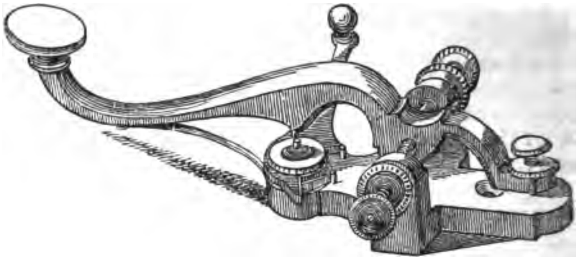
u, the base of the magnet.

Fig. 84.



The form recommended for the key commutator is represented in its proper magnitude in fig. 85 (p. 46). When the key is held down the circuit is perfect. It is not liable to wear and to produce a doubtful connection. The whole arrangement is designed to avoid the evils heretofore existing, and perfect every questionable part. The anvil of the key is well made, firm, and capable of hard wear, regardless of the adjustment of the key lever. The hammer of the key lever is also firm, and made of good platina wire, and securely made fast in the key lever. The adjusting screws of the axle are arranged according to the best mode, to secure the most perfect action. The elevation of the key lever can be adjusted to suit the operator, by elevating the key frame, or otherwise.

Fig. 85.



FROMENT'S WRITING TELEGRAPH.

207. This apparatus is represented in fig. 86 (p. 49), and the principle on which it acts has been fully explained in (153).

The paper upon which the telegraphic characters are written is rolled upon the surface of a drum *c*. The pencil *b* is pressed by a spring upon the paper. The drum is made to revolve by clock-work in the usual manner contained in the case *h*. If the paper be moved without moving the pencil, the latter will trace a straight line; but if the pencil be moved to and fro by the action of the electro-magnet and recoil spring, a zigzag line will be formed by the vibrations imparted to the pencil by the magnet, or what is the same, by the pulsations of the current.

To equalise the wear of the pencil, a slow motion of rotation is imparted to it by wheels adapted for that purpose.

The commutator by which the pulsations which determine the signals are produced, is a wheel, at the circumference of which are five metallic divisions with intermediate spaces vacant, so that in each revolution the current is transmitted five times, and suspended five times. If it be desired to produce a single pulsation, the wheel is moved through the fifth part of a revolution; if it be desired to produce three pulsations it is moved through three-fifths of a revolution, and so on. For each pulsation, one zigzag is made by the pencil at the station to which the despatch is transmitted.

The signs adopted in this telegraph to express the letters, are various numbers and combinations of zigzag forms.

BAIN'S ELECTRO-CHEMICAL TELEGRAPH.

208. The manner in which the decomposing power of the current is capable of producing written characters at a distance from the hand of the writer has been already explained (170).

Of the forms of telegraph in which this principle is brought into play, the only one which has been practically applied on an extensive scale is that projected by Mr. Alexander Bain.

209. To render this instrument understood, let us suppose a sheet of writing paper to be wetted with a solution of prussiate of potash, to which a little nitric and hydrochloric acid have been added. Let a metallic desk be provided corresponding in magnitude with the sheet of paper, and let this desk be put in communication with a galvanic battery so as to form its negative pole. Let a piece of steel or copper wire forming a pen be put in connection with the same battery so as to form its positive pole. Let the sheet of moistened paper be now laid upon the metallic desk, and let the steel or copper point which forms the positive pole of the battery be brought into contact with it. The galvanic circuit being thus completed, the current will be established, the solution with which the paper is wetted will be decomposed at the point of contact, and a blue or brown spot will appear. If the pen be now moved upon the paper, the continuous succession of spots will form a blue or brown line, and the pen being moved in any manner upon the paper, characters may be thus written upon it as it were in blue or brown ink.

An extremely feeble current is sufficient to produce this effect; but it will be necessary, when the strength of the current is very much reduced, to move the pen more slowly, so as to give the time necessary for the weakened current to produce the decomposition. In short, a relation exists between the greatest speed of the pen which is capable of leaving a mark, and the strength of the current; the stronger the current the more rapidly may the pen be moved. In this manner, any kind of writing may be inscribed upon the paper, and there is no other limit to the celerity with which the characters may be written, save the dexterity of the agent who moves the pen, and the sufficiency of the current to produce the decomposition of the solution in the time which the pen takes to move over a given space of the paper.

210. The electro-chemical pen, the prepared paper, and the metallic desk being understood, we shall now proceed to explain the manner in which a communication is written at the station where it arrives.

211. The metallic desk is a circular disk, about twenty inches in diameter. It is fixed on a central axis, with which it is capable of revolving in its own plane. An uniform movement of rotation is imparted to it by means of a small roller, gently pressed against its under surface, and having sufficient adhesion with it to cause the movement of the disk by the revolution of

the roller. This roller is itself kept in uniform revolution by means of a train of wheel-work, deriving its motion either from a weight or main spring, and regulated by a governor or fly. The rate at which the disk revolves may be varied at the discretion of the superintendent, by shifting the position of the roller towards the centre; the nearer to the centre the roller is placed, the more rapid will be the motion of rotation. The moistened paper being placed on this disk, we have a circular sheet kept in uniform revolution.

The electro-chemical pen, already described, is placed on this paper at a certain distance from its centre. This pen is supported by a pen-holder, which is attached to a fine screw extending from the centre to the circumference of the desk in the direction of one of its radii.

On this screw is fixed a small roller, which presses on the surface of the desk, and has sufficient adhesion with it to receive from it a motion of revolution. This roller causes the screw to move with a slow motion in a direction from the centre to the circumference, carrying with it the electro-chemical pen. We have thus two motions, the circular motion carrying the moistened paper which passes under the pen, and the slow rectilinear motion of the pen itself directed from the centre to the circumference. By the combination of these two motions, it is evident that the pen will trace upon the paper a spiral curve, commencing at a certain distance from the centre, and gradually extending towards the circumference. The intervals between the successive coils of this spiral line will be determined by the relative velocities of the circular desk, and of the electro-chemical pen. The relation between these velocities may likewise be so regulated, that the coils of the spiral may be as close together as is consistent with the distinctness of the traces left upon the paper.

A view of the circular desk, the chemical pen, and the clockwork is given in fig. 87 (p. 65), which will render the preceding explanation more easily understood.

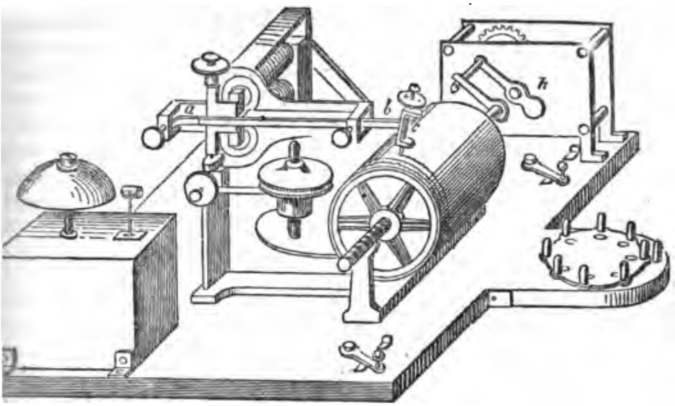


Fig. 86.—FROMENT'S WRITING TELEGRAPH.

THE ELECTRIC TELEGRAPH.

CHAPTER X.

212. Operation of Bain's telegraph.—213. Its commutator.—214. Its extraordinary speed of transmission.—215. Obstructions to its practical application.—216. Its prospects.—217. Autograph telegraph. —218. House's printing telegraph.—219. Its operation.—220. Henley's magnetic telegraph.—221. Brett's printing telegraph.—222. Celerity of telegraphic communication.—223. Circumstances which affect it.—224. Comparative ability of telegraphists.—225 Each telegraphist known by his manner of transmitting.—226. Easier to transmit than to receive.—227. Pauses in transmission.—228. Rate of transmission with double needle instruments worked by voltaic current.—229. Rate with magneto-electric current.

212. Now, let us suppose that the galvanic circuit is completed in the manner customary with the electric telegraph, that is to say, the wire which terminates at the point of the electro-chemical pen is carried from the station of arrival to the station of departure, where it is connected with the galvanic battery, and the returning current is formed in the usual way by the earth itself. When the communication between the wire and the galvanic battery at the station of departure is established, the current will pass through the wire, will be transmitted from the point of the electro-chemical pen to the moistened paper, and will,

as already described, make a blue or brown line on this paper. If the current were continuous and uninterrupted, this line would be an unbroken spiral, such as has been already described; but if the current be interrupted at intervals, during each such interval the pen will cease to decompose the solution, and no mark will be made on the paper. If such interruption be frequent, the spiral, instead of being a continuous line, will be a broken one, consisting of lines interrupted by blank spaces. If the current be allowed to act only for an instant of time, there will be a blue or brown dot upon the paper; but if it be allowed to continue during a longer interval, there will be a line.

Now, if the intervals of the transmission and suspension of the current be regulated by any agency in operation at the station of departure, lines and dots corresponding precisely to these intervals, will be produced by the electro-chemical pen on the paper, and will be continued regularly along the spiral line already described. It will be evident, without further explanation, that characters may thus be produced on the prepared paper corresponding to those of the telegraphic alphabet already described in the case of Morse's telegraph, and thus the language of the communication will be written in these conventional symbols.

There is no other limit to the celerity with which a message may be thus written, save the sufficiency of the current to effect the decomposition while the pen passes over the paper, and the power of the agency used at the station of departure to produce, in rapid succession, the proper intervals in the transmission and suspension of the current.

The succession of intervals of transmission and suspension of the current on which the production of the written characters on the prepared paper depends, may obviously be produced by the key commutator (128); and with that instrument at the station from which the dispatch is transmitted, an agent can convey in the same manner and with the same celerity as in the case of the telegraph of Morse, or that of Froment; and such is in fact the manner in which dispatches are usually transmitted with this apparatus.

213. But this form of commutator, though perfectly efficient so far as it goes, does not call into operation all that extraordinary celerity which forms the prominent feature of this invention, and of which a remarkable example has been already mentioned in the case of the experiments performed by M. Le Verrier and myself before the Committees of the Institute and the Legislative Assembly at Paris, which were made with these instruments, and, as we have stated, dispatches were

sent along a thousand miles of wire, at the rate of nearly 20000 words an hour.

We shall now explain the means by which this extraordinary feat is accomplished. The despatch must pass through the following preparatory process:—

A narrow ribbon of paper is wound on a roller, and placed on an axis on which it is capable of turning so as to be regularly unrolled. This ribbon of paper is passed between rollers under a small punch, which striking upon it makes a small hole at its centre. This punch is worked by a simple mechanism so rapidly, that when it is allowed to operate without interruption on the paper passing before it, the holes it produces are so close together as to leave no unperforated space between them, and thus is produced a continuous perforated line. Means, however, are provided by which the agent who superintends the process, can, by a touch of the finger, suspend the action of the punch on the paper, so as to allow a longer interval to elapse between its successive strokes upon the paper. In this manner a succession of holes are perforated in the ribbon of paper, separated by unperforated spaces. The manipulator, by allowing the action of the punch to continue uninterrupted for two or more successive strokes, can make a linear perforation of greater or less length on the ribbon, and by suspending the action of the punch these linear perforations may be separated by unperforated spaces.

Thus it is evident, that being provided with a preparatory apparatus of this kind, an expert agent will be able to produce on the ribbon of paper as it unrolls, a series of perforated dots and lines, and that these dots and lines may be made to correspond with those of the telegraphic alphabet already described.

Let us imagine, then, the agent at the station of departure preparing to despatch a message. Preparatory to doing so, it will be necessary to inscribe it in the perforated telegraphic characters on the ribbon of paper just described.

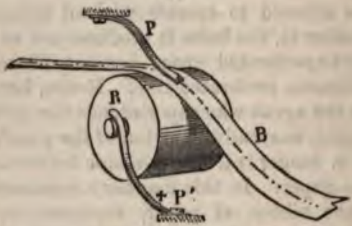
He places, for this purpose, before him the message in ordinary writing, and he transfers it to the ribbon in perforated characters by means of the punching apparatus. By practice he is enabled to execute this in less time than would be requisite for an expert compositor to set it up in common printing type.

The punching apparatus for inscribing in perforated characters the dispatches on ribbons of paper is so arranged, that several agents may simultaneously write in this manner different messages, so that the celerity with which the messages are inscribed on the perforated paper may be rendered commensurate with the rapidity of their transmission by merely multiplying the inscribing agents.

Let us now imagine the message thus completely inscribed on the perforated ribbon of paper. This ribbon is again rolled as at first upon a roller, and it is now placed on an axle attached to the machinery of the telegraph.

The extremity of the perforated ribbon at which the message commences is now carried over a metallic roller, which is in connexion with the positive pole of the galvanic battery. It is pressed upon this roller, as represented in fig. 88, by a small

Fig. 88.



metallic spring, terminating in points like the teeth of a comb, the breadth of which is less than that of the perforations in the paper. This metallic spring is connected with the conducting wire which passes from the station of departure to the stations of arrival. When the metallic spring falls into the perforations of the ribbon of paper as the latter passes over the roller, the galvanic circuit is completed by the metallic contact of the spring with the roller; but when those parts of the ribbon which are not perforated pass between the spring and the roller, the galvanic circuit is broken and the current is interrupted.

A motion of rotation, the speed of which can be regulated at discretion, is imparted to the metallic roller by clockwork or other means, so that the ribbon of paper is made to pass rapidly between it and the metallic spring, and, as it passes, this metallic spring falls successively into the perforations on the paper. By this means the galvanic circuit is alternately completed and broken, and the current passes during intervals corresponding precisely to the perforations in the paper. In this manner the successive intervals of the transmission of the current are made to correspond precisely with the perforated characters expressive of the message, and the same succession of intervals of transmission and suspension will affect the writing apparatus at the stations of arrival in the manner already described.

214. Now there is no limit to the speed with which this process can be executed, nor can there be an error, provided only that

the characters have been correctly marked on the perforated paper; but this correctness is secured by the ribbon of perforated paper being examined after the perforation is completed and deliberately compared with the written message. Absolute accuracy and unlimited celerity are thus attained at the station of departure. To the celerity with which the dispatch can be written at the station of arrival there is no other limit than the time which is necessary for the electric current to produce the decomposition of the chemical solution with which the prepared paper is saturated.

215. It may be asked then why this form of telegraph, affording as it does the means of obtaining a celerity of transmission so far exceeding any other that has been projected, has not been universally adopted?

To this it may be answered that the celerity here described can only be attained after the dispatch to be transmitted has been marked in the pierced telegraphic characters on the ribbon of paper, and that the process of so marking it would not be more rapid, however expert the operator might be, than that by which the same operator would transmit the same dispatch directly by the key commutator, either with this telegraph or those described in (191, 192). If, therefore, the time necessary to commit the dispatch in telegraphic characters to the perforated ribbon of paper, be included in the estimate of the time of its transmission from station to station, this form of telegraph is not only slower and consequently less efficient than either of those described in (191, 192), but it is slower than any other form of telegraph whatever.

It must therefore be admitted, that, so long as the demands upon the conducting wires do not exceed their powers of transmission by the operation of the ordinary methods now commonly practised, the contrivance of Mr. Bain can present no very strong claims for preference over the other systems. But if the demands of the public should be greatly multiplied, as they certainly would be by lowering the tariff, then the method above described would be presented under different conditions, and might become the only expedient of all those hitherto contrived, by which such augmented demands could be satisfied.

216. If for example the time should arrive when a much more considerable share of the demands now satisfied by the post-office should be transferred to the telegraph; if instead of short and unsatisfactory dispatches conveying political and general intelligence to the journals, fully detailed circumstantial statements and reports were required; if the same full reports of speeches and debates, on occasions of great public interest, or reports of any

proceedings or events of adequate importance, taking place at a distance, which are now transmitted through the post-office were required to be sent by telegraph, it is clear that the apparatus now in common use, of whatever form, would be utterly inadequate to the satisfaction of such demands.

But how, it will be asked, would the system of Bain be more efficient? The answer is obvious. Nothing more would be necessary than to engage a greater number of persons for the purpose of committing the dispatches to the perforated ribbons. If a great number of dispatches, short or long, be brought at once into the telegraphic office for transmission, let them be immediately distributed among a proportionate number of the persons engaged in the preparation of the ribbons. A long dispatch might be divided into several portions, and distributed among several, just as a manuscript report intended for publication in a journal is distributed among several compositors. When the despatches thus distributed should be committed to the ribbons, these ribbons might be connected together so as to form longer continuous ribbons, which being put into the telegraphic instruments would be sent to their destination at the rate of 20000 words an hour on each wire.

A mercantile firm, or the correspondent of a journal might, if they were so minded, have their own punching apparatus and their own telegraphic cipher, and instead of sending to the telegraphic-office a manuscript dispatch they would send a ribbon of paper containing the dispatch marked upon it, which being put directly into the instrument would be instantly transmitted to its destination. And this would be attended with the further advantage that the contents of the dispatch would be concealed from the agents themselves employed in its transmission. The party to whom the dispatch is addressed would in this case receive the sheet taken from the instrument written in the cipher of which he alone would possess the key.

It often happens, especially in the business of government or that of journalism, that the same dispatch is required to be transmitted to many different places in different directions. By the system of Bain this would be easily accomplished. The same ribbon which sends the dispatch in one direction may be transferred immediately to another instrument acting upon another line of wire, or even remaining in the same instrument the transmission may be repeated, changing the direction by a commutator.

If it were required no great difficulty would be presented by the process of perforating two or more ribbons at once with the same dispatch. The process would not be slower than that required for a single ribbon, and in that case the several ribbons might be

at the same time sent to different telegraphic stations, and their contents transmitted in various directions.

In this view of the question, the system of Bain is to the common telegraph what the steam-engine is to the horse, the power to the hand-loom, the lace-frame to the cushion, the self-acting mule to the distaff, or the stocking-frame to the knitting-needle.

217. A modification of the electro-chemical telegraph has been contrived, by which a dispatch may be transmitted to any distant station, and then delivered in the handwriting of the person who transmits it.

By this method, a person at any station, as for example at London, may write a communication in characters used in common writing or printing on paper placed at another distant station, as for example at Trieste, and this writing shall be traced on the paper with as much precision as if the person writing held the pen in his hand.

We may imagine that the electro-chemical pen placed on the paper at Trieste is extended to London, and there held and directed by the hand of the writer, for this it is which almost literally takes place. The conducting wire, in connection with that part of the electro-chemical pen which is held in the hand, which extends from Trieste to London, may be considered as only forming part of this pen, and the end of such pen at London, held and directed by the hand of the writer, will communicate a motion to its point at Trieste, in exact correspondence with the characters formed by the hand of the writer.

Thus, if the writer at London move the extremity of the conducting wire so as to write a phrase or his usual autograph, the point at Trieste will there inscribe on the prepared paper the same phrase with the same signature annexed, and the writing of the phrase and the signature will be identical with that of the writer.

In the same manner a profile or portrait, or any other outline drawing may be produced at a distance. The methods of accomplishing this depend, like the other performances of electricity in this application of it, on the alternate transmission and suspension of the current, and on its decomposing power; but as they are at present more matters of curiosity than of practical utility, we shall not detain the reader here with any more detailed notice of them.

HOUSE'S TELEGRAPH.

218. This apparatus, which is in extensive use in the United States, is an example of the class of printing telegraphs, that is

instruments which print in the ordinary letters the dispatch at the station to which it is addressed, by means of a power worked at the station from which it is transmitted. In a certain sense, this is accomplished by the three forms of telegraph described in (202, 203, and 204); but in these cases the dispatch is printed or written in cipher, which is attended with the inconvenience of being understood only by those who possess, and are sufficiently familiar with the key. The process of deciphering it, and writing it in common characters, occupying more or less time, for some purposes, such for example as that of journalism, this time must be taken into account in estimating the practical celerity of communications, inasmuch as the dispatch until so interpreted, is not available to the parties to whom it is addressed.

A telegraph which instead of impressing on paper characters in cipher, would impress the characters of common letter-press, even though these should be transmitted and impressed at a slower rate than that of the transmission of the characters in cipher, might nevertheless be, in effect, more expeditious, more time being saved by superseding the process of interpreting the cipher than is lost by the relative slowness of the transmission.

It is evident that these observations, being general, are applicable, not only to the instrument we are now about to describe, but to all others of the same class.

219. House's printing telegraph, like all other telegraphic instruments, consists of two distinct parts, a commutating apparatus to govern the transmission of the current, and a printing apparatus upon which the current arriving from a distant station operates.

The manner in which the transmission of the current is controlled by the keys of the finger-board, is substantially the same as in Froment's telegraph already described. The wheel, however, that produces by its revolution the pulsations of the current, is moved, not as in Froment's by clock-work, but by the foot of the operator, acting upon a treddle like that of a lathe which is seen under the case of the commutator in the fig. 89 (p. 81).

The rotation of this wheel is arrested at the point corresponding to any desired letter, by putting down with the finger the key upon which that letter is engraved, in exactly the same manner and by the same mechanical expedient as in Froment's telegraph.

The keys, upon the key-board of this instrument, govern by means of the pulsations of the current the motion and position of a dial or wheel at a distant station, inscribed with similar characters in the same manner as has been already explained in

the case of the French railway telegraphs, and in that of the telegraph explained in (201).

Let us then suppose that by putting down any key, that inscribed with A for example at the station S, a certain dial or wheel at S′, having upon it letters corresponding with those of the key-board at S, is so moved that the letter A is brought into a certain position. The letters upon this wheel are formed in relief like type, and when successively brought into the necessary position by the action of the current, having previously passed in contact with an inking apparatus, a band or ribbon of paper is pressed against them by means provided at the station S′, and the impression of the letter is made upon the paper. By the next action of the current, the succeeding letter transmitted is brought to the same position, the ribbon of paper being meanwhile drawn forward, another impression takes place, and so on.

The apparatus by which the ribbon of paper is moved, the type inked, and the paper pressed against it is not worked by the current. That process is effected by mechanism put in operation by the agent at the station at which the dispatch is received.

In the figure, the ribbon of paper is represented at F, upon a roller from which it is gradually drawn, as letter by letter the words of the dispatch are impressed upon it. The black band which appears upon another roller is an endless strap by which the types are inked.

In the mechanism as well of the transmitting as of the receiving apparatus, there are many details showing much ingenuity of contrivance, and resources of invention, which, however, are too complicated to admit of any clear exposition without numerous plans and sections, and which we must pass over.

The printing apparatus, at the station at which the dispatch is received, is put in operation by the action upon the treddle, in the same manner as in the transmitting apparatus at the other station.

The galvanic apparatus, which supplies the current for working this apparatus, is the battery of Grove, described in (34). About thirty cylindrical pairs are necessary for a distance of 100 miles.

The first line operating with this apparatus was established between New York and Philadelphia in 1849.

nication, differs very much when one form of telegraphic instrument or one pair of operators is compared with another.

The profitable result of the operation of any telegraph is evidently measured by the number of words which it is capable of transmitting in such a shape as to be intelligible by the party to whom the message is addressed, in a given time. This, which we shall call the celerity of transmission, and which is quite distinct from the velocity with which electric signals are conveyed from station to station, is therefore a most important element in the estimation of the value of any telegraphic apparatus.

223. This celerity of transmission depends upon a great number of circumstances, several of which are independent of the telegraphic apparatus. The principal of these are :—

1. The skill and agility of the transmitting agent.
2. The quickness of eye, activity and attention of the receiving agent.
3. The instrument used for transmission.
4. The instrument used for reception.
5. The distance to which the dispatch is transmitted.
6. The insulation more or less perfect of the line wires.
7. The weather.

With all and each of these conditions and qualities the celerity with which the dispatches are received and rendered available at their place of destination, varies, and with some of them this variation extends to very wide limits.

224. Different telegraphists have very different powers as to celerity. These powers depend on practice as well as upon natural ability and aptitude, and on manual dexterity. Not only is it necessary to transmit the signals in quick succession, but to do so with such distinctness that they shall be readily interpreted, and such correctness as to render repetitions unnecessary. In this respect telegraphists having equal practice differ one from another as much as do clerks, some writing rapidly and legibly, some rapidly but not legibly, some legibly but not rapidly, and some neither rapidly nor legibly. The relative ability of telegraphists in this respect is partly mental and partly mechanical, depending as much upon quickness of intelligence, attention, and observation, as upon manual dexterity and address.

The great liability to delay, arising from the failure of the transmitter to render himself understood by the receiver, is rendered manifest by the fact that in all telegraphs conventional signs are established for the words, "wait," "repeat," "not understood," "understood," "proceed," and the like. When the transmitter is going on faster than the receiver can take down *the* words or understand them, then the latter remits the sign to

magnetism to these. These electro-magnets act upon a small permanent magnet suspended under the desk, on the axis of the indicating needle, and parallel to it. They deflect this needle on the one side or the other, at the moment they receive the magnetism from the current, and their deflection is continued by the effect of the induced magnetism produced by the permanent magnet on the electro-magnet.

When the handle is raised, the momentary current being reproduced, but in the contrary direction, the polarity of the electro-magnet at the distant station is reversed, and the needle is deflected in the same manner to the other side.

BRETT'S PRINTING TELEGRAPH.

221. Mr. Brett, who has obtained such well-merited celebrity by his successful exertions in establishing electric communication by submarine cables between the United Kingdom and the continent of Europe, and more recently between the continents of Europe and Africa, took out, conjointly with Mr. House, a patent for a printing telegraph, the original form of which is represented in fig. 92 (p. 113).

The apparatus, like that of House's American telegraph, already described, consists of a key-board, which is the transmitting apparatus or commutator, and does not differ in any important particular from that already described. The receiving and pointing apparatus is also very similar, and stands upon the key-board. In front of it is an indicating dial, the hand upon which points successively to the letters printed upon the scroll of paper by the apparatus behind the dial. The printing apparatus, with some modifications, is similar to that of House.

This telegraph is, or was, lately exhibited at work in the Panopticon of Science, in Leicester Square.

The Messrs. Brett are understood, however, to be engaged upon the construction of an instrument which is expected to attain the same objects in a more satisfactory manner.

CELERITY OF TRANSMISSION.

222. Although it be true that the signals made at any one telegraphic station are rendered instantaneously apparent at another, no matter how distant, it must not therefore be inferred that the transmission of messages by the telegraph is equally instantaneous. Not only is this not the case, but the celerity with which messages are conveyed between station and station, so as to be rendered practically available for the purposes of intercommu-

attitudes of the arms, as in the French State instruments, or pointers directed to the letters or figures on a dial, as in the railway instruments, the celerity of the transmission must be determined by the power of the less able of the two agents, the transmitter and receiver. If the transmitter be able to send the letters more rapidly than the receiver can read and take them down, he must moderate his pace to the limit determined by the power of his correspondent. If the receiver be capable of reading and taking down faster than the transmitter is able to send the letters, his superior force is useless. He can only write the dispatch as fast as he receives it. To send dispatches with the greatest advantage of celerity, the agents yoked to corresponding instruments ought to be selected of as nearly equal ability as possible, since the slower of a pair necessarily neutralises the superior skill of his fellow, and the dispatch would proceed with equal celerity if he were yoked with a less able correspondent.

As quickness of hand is essential to the transmitter, quickness of eye is necessary to the receiver.

227. In all forms of telegraph which express the letters by signals, such as the needle telegraph, and the French State telegraph, a certain pause is necessary between letter and letter, to prevent the signals being confounded one with another. In the single needle instrument, the letters being expressed by from one to four deflections of the needle, and in the double needle, from one to two, the mean time of each letter is that of two and a half deflections in the one, and one and a half in the other, the intervals between letter and letter being the same in both. Owing to the slowness of transmission of the single needle instrument, it is only used between secondary stations, where there is but little business. It must, however, be remembered, in comparing the relative celerity of different instruments, that the double needle instrument, as well as the French State telegraph, is, in fact, two independent telegraphs, having not only separate and independent transmitting and indicating apparatus, with their respective accessories, batteries, &c., but separate and independent conducting wires. It is, in effect, as if two equally powerful and independent steam engines were united in the same work, in order to obtain double power.

228. In 1850, Mr. Walker made some calculations, with the view to determine the average celerity of transmission at that time with the double needle instrument in the hands of competent operators, and published the results in his work on electric telegraph manipulation. Eleven messages were timed, all of more than the usual length, the shortest consisting of 73 and the longest of 364 words. The total number of words was 2638, and,

consequently, their average length was 240 words. The total time of transmission was 162 minutes, and, consequently, the average number of words transmitted, per minute, was 16¼. The greatest speed of transmission was 20½, and the least 8¼ words per minute.

As it might be considered probable that four or five years' general experience and practice might have improved the ability of the operators, I applied to the secretary of the Electric Telegraph Company, Mr. Foudrinier, requesting him to cause a sufficient number of messages, transmitted in the ordinary course of business with the double needle instrument, to be timed, which he was so obliging as to do, in June, 1854, and the following were the results:—

11 Messages.—Number of words in the addresses	. .	84
,, ,, ,, messages	. . .	160
Total number of words transmitted	.	244
Total time of transmission	. . . . .	689 seconds.
Average number of words transmitted per minute	. .	21¼

It appears, therefore, that the average celerity of transmission with this instrument has increased in the ratio of about 16 to 21.

The greatest celerity of transmission was, in this case, 24½, and the least 16¾ words per minute.

229. The manner in which the magnetic electric current affects the needle in the arrangement adopted by the Magnetic Telegraph Company, being somewhat different from that produced in the common needle instruments, worked by the Electric Telegraph Company, although the systems of telegraphic signals are not essentially different, it appeared to me to be not impossible that the difference between the instruments might more or less affect the celerity of transmission. I therefore requested Mr. Bright, the Secretary of the Magnetic Company, to time a series of dispatches transmitted in the ordinary course of business. This was accordingly done on the 28th of June, 1854, and the following were the results:—

74 Messages.	Total number of words	. . . .	2792
	Time of transmission	. . .	$102^m\ 8^s$
	Average number of words per minute	. . .	27⅓

The greatest celerity of transmission attained in this series of messages was 37⅕ words per minute.

The entire series consisted of messages transmitted from London to Liverpool, on a pair of double needle instruments, at different times of the day, and were carefully tabulated. In the series, several messages were included, the transmission of which was exceptionally slow, owing either to the difficult nature of the communications, consisting of long words in private cipher, or of the names

of foreign towns, or, in fine, from the inaccuracy or slowness of the transmitting clerk in London. It would seem, therefore, that this series of messages includes fair conditions for an average result.

It would, therefore, appear that the needle instruments worked by the magneto-electric current used by this company are, *ceteris paribus*, susceptible of greater celerity of transmission than the instruments in which the needles are affected by the common voltaic current, in the ratio of about 27 to 21, or 9 to 7.

One of the causes which has been assigned to this increased efficiency, is the fact that the needles of the magnetic instruments have a *dead beat*, while those of the voltaic instruments, in striking the stops, have a recoil, and vibrate two or three times before they come to rest. Whether this be the real cause of the difference, further experience must prove, but it is difficult to imagine that it can be due to any cause independent of the instruments, seeing the large number of messages from which the average has been computed.

Fig. 87.—BAIN'S ELECTRO-CHEMICAL TELEGRAPH.

THE ELECTRIC TELEGRAPH.

CHAPTER XI.

230. Illustration of the efficiency of the needle instruments.—231. Rate of transmission with the French state telegraphs.—232. With the French railway telegraphs.—233. With the Morse telegraph.—234. Discrepancy of reports.—235. Causes of its celerity.—236. Rate with Bain's telegraph.—237. Transmission of music.—238. Rate of transmission with House's telegraph.—239. Distance sometimes affects celerity.—240. Examples of distant transmissions in U. S.—241. Advantages of uniform organisation.—242. Uses of the electric telegraph.—243. Subject of dispatches.—244. Effect of the tariff.—245. Uses of the telegraph in railway business.—246. Portable railway telegraph.—247. Practical uses on railways.—248. Its economical advantages.

230. Mr. Walker, writing in 1850, gives the following illustration of the efficiency which has been attained in the working of the needle system, and in the management generally of the telegraphic business:—

"The rate at which newspaper dispatches are transmitted from Dover to London, is a good illustration of the perfect state to which the needle telegraph has attained, and of the apt manipulation of the officers in charge. The mail, which leaves Paris

about mid-day, conveys to England dispatches containing the latest news, which are intended to appear in the whole impression of the morning paper. To this end, it is intended that a copy be delivered to the editor in London about three o'clock in the morning. The dispatches are given in charge to us at Dover soon after the arrival of the boat, which of course depends on the wind and the weather. The officer on duty at Dover, having first hastily glanced through the manuscript to see that all is clear to him and legible, calls 'London' and commences the transmission. The nature of these dispatches may be daily seen by reference to 'The Times.' The miscellaneous character of the intelligence therein contained, and the continual fresh names of persons and places, make them a fair sample for illustrating the capabilities of the electric telegraph as it now is. The clerk, who is all alone, placing the paper before him in a good light, and seated at the instrument, delivers the dispatch, letter by letter, and word by word, to his correspondent in London; and although the eye is transferred rapidly from the manuscript copy to the telegraph instrument, and both hands are occupied at the latter, he very rarely has cause to pause in his progress, and as rarely also does he commit an error. And, on account of the extremely limited time within which the whole operation must be compressed, he is not able, like the printer, to *correct his copy*.

"At London there are two clerks on duty, one to read the signals as they come, and the other to write. They have previously arranged their books and papers: and, as soon as the signal for preparation is given, the writer sits before his manifold book, and the reader gives him distinctly word for word as it arrives; meanwhile, a messenger has been dispatched for a cab, which now waits in readiness. When the dispatch is completed, the clerk who has received it reads through the manuscript of the other, in order to see that he has not misunderstood him in any word. The hours and minutes of commencing and ending are noted, and the copy being signed is sent under official seal to its destination, the manifold facsimile being retained as our office copy, to authenticate verbatim what we have delivered. This copy and the original meet together at the chief telegraph office at Tunbridge, early in the day, and are compared. When the work is over, and the dispatches have reached their destination, the clerks count over the number of words and the number of minutes, and find the rate per minute."

231. The signals adopted to express the letters in the French State telegraph being each made by a single motion of the arms, they necessarily are produced with greater celerity than the multiplied deflexions of the needle-instruments. Like the double needle-instrument, the French telegraph is composed in fact of two

completely independent telegraphic instruments, with two independent conducting wires, and its celerity of transmission is due to their combined powers.

It is stated by the directors of the administration that the average transmitting powers of these telegraphs is nearly 200 letters or signs per minute.

232. The alphabetical telegraphs, of which the French railway telegraph may be taken as an example, are much slower in their rate of transmission. M. Breguet, who has constructed those worked in France, and superintended and directed their operation, says, that their average rate of transmission, when fairly worked, is about 40 letters per minute.

233. The writing and printing telegraphs are independent of a receiving agent, the receiving apparatus in all these being automatic. All these instruments have an advantage over the English and French telegraphs, inasmuch as they employ only one conducting wire, and those who print the dispatch in the common letter-press characters, have the further advantage of being wholly independent of the skill of any agent to interpret or decipher them.

The celerity of transmission attainable with the Morse telegraph, which of all the forms of telegraphic apparatus hitherto invented is the most extensively used, is very considerable, but varies perhaps still more than the needle-instruments, with the skill of the telegraphist.

In this instrument, it will be remembered that the transmitting agent plays upon a key-commutator, the letters being severally expressed by repeated touches of the key succeeding each other, after longer or shorter intervals. At the station receiving the dispatch, the armature of the electro-magnet moves simultaneously with the transmitting key, and at each of its motions towards the magnet, it produces a distinctly audible click. The receiving agent acquires by practice such expertness and quickness of ear, that by listening to this clicking he is able to interpret the dispatch, and to write it down or dictate it to a clerk without using the apparatus for impressing it upon the paper ribbon.

Different telegraphists acquire this power of oral interpretation of the dispatches with different degrees of facility and precision; but all are more or less masters of it. So much so, that in most cases on the American lines, it is by the clicking of the magnet that the messages are taken down, being afterwards corrected, if necessary, by comparison with the indented paper ribbon.

The telegraphist is placed at a table, upon which the instrument stands, having before him the paper upon which the message is to be written, and at his left a provision of blacklead pencils ready

cut and pointed, usually half a dozen. When the transmission of the message commences, the electro-magnet dictates it to him, letter by letter, at the same time indenting it upon the paper ribbon. He writes it down, and, in general, it is delivered by the magnet as fast as he can write it, availing himself of all such abbreviations as are intelligible to those who may have to read it. As the points of the pencils are successively worn he lays them on the table at his right hand. A person engaged exclusively in that process, visits his table from time to time, repoints the pencils lying on his right, and replaces them on his left. This person passes round the telegraph office, from table to table, keeping up a constant supply of properly pointed pencils at the hand of each telegraphist.

The most expert telegraphists are able to take down the messages in this manner by ear, without any reference to the ribbon, and so correctly that there is no need of subsequent verification. When the message is concluded, the sheet on which it is written is handed to another clerk, who is provided with a stock of envelopes, in one of which he encloses it; and, writing the address upon it, delivers it to a messenger, who forwards it to the party to whom it is addressed. Meanwhile the paper ribbon, on which the message has been indented in the telegraph ciphers, is cut off, folded up, and preserved for reference.

It is only, however, the most expert class of telegraphists that can operate in this way. Others, less able, are always obliged to verify and correct what they have taken down, by comparison with the indented ribbon, after the message has been concluded; while others less able still, cannot trust themselves to take down *by ear*, and sit before the ribbon as it is discharged from the roller, writing out the message from it *by eye*.

The salariês allowed to different agents vary according to the skill they attain in these operations. One who acquires the power of taking down rapidly and correctly *by ear* will receive twice the amount allowed to him who can only take down *by eye*, the latter being always much slower than the former.

It often happens that the power of interpreting easily and correctly *by ear* is very important, as in the case in which the mechanism of the instrument for moving and indenting the paper may have been accidentally deranged and disabled, or in which the office may be deficient in its supply of paper ribbon.

By the oral method of reception the entire receiving apparatus, except the electro-magnet and its armature, is dispensed with.

If a mistake is committed by the transmitting agent, in consequence of which a word or phrase is unintelligible, the receiving agent intercepts the current, and signifies that the word is to

be repeated, and at the same time tears off the erroneous part of the ribbon. This, however, is a circumstance of rare occurrence.

When a very long dispatch is transmitted, and arrives with greater celerity than that with which an agent can transcribe it, the ribbon may be divided, and two agents put to work at once at its transcription. The reports of congress and public meetings transmitted to the journals, afford examples of this.

These reports may be, by one operation, transmitted to all the towns upon the same telegraphic line.

In some cases long dispatches, such as those addressed to the journals, are expedited by two or more instruments on different wires. The dispatch is, in this case, divided into two or more parts, marked 1, 2, 3, or A, B, C, &c., and these parts are simultaneously transmitted to their destination, being reunited there after their arrival. This expedient, however, can only be resorted to where there are two or more line wires, which is a rare case in the United States.

234. If the celerity of transmission of the Morse instrument be compared with that of the English and French telegraphs, it must not be forgotten that the latter require two wires, while the former requires but one. In the transmission and reception of a dispatch both, however, employ the same number of agents.

There is great discrepancy in the reported estimates of the celerity of transmission of the Morse telegraphs, owing probably to the varying skill of the telegraphists on whose performance such estimates have been based.

According to Mr. Turnbull, the average celerity of transmission of this telegraph is from 135 to 150 letters per minute.

In a report made by Mr. O'Reilly, the director of one of the most extensive of the New York Companies, it is stated that the average rate of transmission is from 20 to 23 words per minute. Since it is generally estimated that the average length of telegraphic words is five letters and a half, this would amount to 110 to 127 letters per minute.

Mr. O'Reilly adds, however, that a "higher rate of transmission could be obtained, but as nearly all operators copy from their instruments, and reduce the messages to ordinary writing as they arrive, the rate of 20 to 23 words is considered rapid enough, as an expert operator can indent his Morse characters faster than most men can write the words they express with a pen or pencil."

We may perhaps take 150 letters as a fair estimate of the rate of transmission, and it follows therefore that this telegraph is more rapid than the double needle-telegraph in the ratio of about 3 to 2, and since the latter employs two wires with their accessories, while the former employs only one, it follows that the transmitting

power of each wire with the Morse telegraph is three times as great as with the double needle instrument.

235. The causes of this greater celerity are twofold: first, the greater celerity with which the ciphers are impressed upon the ribbon of paper, compared with that with which the visible signals are exhibited and succeed each other in the English and French telegraphs; and secondly, the removal of those delays of transmission which arise from the want of attention or quickness of eye on the part of the agent receiving the dispatch, rendering it necessary to repeat words which have been missed or misunderstood.

In the American offices of the Morse lines, it is stated in the published reports that "there are a number of attendants, each one of whom has his respective department; they are divided into 'copyists, book-keepers, battery-keepers, messengers, line inspectors, and repairers.' The usual charge of transmission is 25 cts., equal to a shilling, for ten words exclusive of the address and the signature sent 100 miles: the messages vary in price from 10 cts., or *5d.*, to 100 dols., or *20l.* The amount of business which a well-conducted office can perform, and the net proceeds arising therefrom, may well excite surprise; a single office in that country, with two wires, one 500, the other 200 miles in length, after spending three hours in the transmission of public news, telegraphed, in a single day, 450 private messages, averaging 25 words each, besides the address and signature, sixty of which were sent in rotation, without a word of repetition."

236. All that has been said above relating to Morse's telegraph may *mutatis mutandis* be applied to other telegraphic instruments, which write in cipher the dispatches by self-acting machinery, such as those described in 191, 192, and 193.

When dispatches are transmitted by means of a key-commutator, with Bain's telegraph, the operation being precisely similar to that of Morse, the celerity of transmission by operators of equal skill ought to be the same. Nevertheless, as these instruments of Bain's, with some modifications, are at present used on certain lines by the Electric Telegraph Company, Mr. Foudrinier has, at my request, caused a series of messages to be timed, of which the following is the summary of the results:—

63 Messages.—Total number of words in the addresses	456
,, ,, ,, messages	991
Total number of words transmitted	1447
Total time of transmission	4454 seconds.
Average number of words transmitted per minute	$19\frac{1}{2}$

It appears, therefore, that as this telegraph is worked in

England, its rate of transmission is slower than the double needle telegraph.

The advantage which attends its use is that it writes the dispatch in cipher, which is preserved in the telegraphic office, so that the labour of a clerk to copy the dispatch for reference is saved.

It would follow from the comparison of this result with the reports of the American telegraph, that the operators with Bain's system in England are not as expert as those of Morse's in America. But when the method of transmitting by a previously-prepared perforated ribbon, described in 194, is resorted to, the apparatus is rendered absolutely automatic, no agency being required either in the transmission or reception, save that required for the perforation of the transmitting ribbon, and the interpretation and transcription of the dispatch delivered in the telegraphic cipher.

Whatever may be thought of the practical difficulties which at present obstruct the application of this method of rapid telegraphic transmission, we cannot help thinking that it has before it a great future, and that when, like the steam-engine as improved by Watt, and the power-loom, it shall have had time to attain a greater degree of practical perfection, and to surmount prejudice and the opposing influence of counter-interests, it may be the means of transferring, to the telegraph, a large part of that business now done by the post-office.

237. It is an amusing fact, that music has actually been transmitted in this way by means of its rhythm. The following is related by an eye-witness of the experiment at New York:—

"We were in the Hanover Street office when there was a pause in business operations. Mr. W. Porter, of the office at Boston, asked what tune we would have. We replied 'Yankee Doodle,' and to our surprise he immediately complied with our request. The instrument commenced drumming the notes of the tune as perfectly and distinctly as a skilful drummer could have made them at the head of a regiment; and many will be astonished to hear that 'Yankee Doodle' can travel by lightning. We then asked for 'Hail, Columbia!' when the notes of that national air were distinctly beat off. We then asked for 'Auld lang syne,' which was given, and 'Old Dan Tucker,' when Mr. Porter also sent that tune, and, if possible, in a more perfect manner than the others. So perfectly and distinctly were the sounds of the tunes transmitted, that good instrumental performers could have had no difficulty in keeping time with the instruments at this end of the wires." *

That a pianist in London should execute a fantasia at Paris,

* Chambers's Papers for the People, vol. ix. No. 71.

Brussels, Berlin, and Vienna, at the same moment and with the same spirit, expression, and precision as if the instruments, at these distant places, were under his fingers, is not only within the limits of practicability, but really presents no other difficulty than may arise from the expense of the performances. From what has been just stated, it is clear that the *time* of music has been already transmitted, and the production of the sounds does not offer any more difficulty than the printing of the letters of a dispatch.

238. A great celerity of transmission is claimed for the printing telegraph of House, so great, that if the claim be well founded, it is a matter of surprise that it has not superseded the Morse telegraph in the United States, where competition is so sharp and action so free. According to Mr. Turnbull, who ought to be considered an impartial assessor, at least between inventors who are both American, the ordinary rate of transmission of the improved House instrument is from 30 to 35 words, printed in full, per minute, which would be from 165 to 200 letters. He adds, that business-messages are sent at the rate of 200 to 250 letters per minute, and that in one case 365 letters, transmitted from New York, have been printed at Utica, distant 240 miles, in one minute.

In a written estimate supplied by the directors of the House lines to Mr. Jones,* it is also stated that, accidents apart, the average number of words transmitted on a single wire per minute and printed in full by the telegraph at their place of destination, is from thirty to thirty-five; but when as in newspapers abbreviations are allowed, the rate is fifty. It is stated for example that the proceedings of the democratic state convention in the autumn of 1850, containing 7000 words, were transmitted from Syracuse to Buffalo in two hours and ten minutes, being at the rate of 54 words per minute. It is evident that in this telegraph, like others, much depends on the ability of the telegraphist, for it is stated that one telegraphist on the line has transmitted 365 letters in a minute, being at the rate of six per second.

When it is considered that this telegraph delivers its messages printed in the ordinary Roman characters, while all the others in practical operation deliver them either in visible signs or written ciphers, which must be interpreted and taken down in ordinary writing before they can serve any useful purpose, the vast superiority of this system of House must be conspicuously manifest, supposing of course that the reports and estimates above produced are verified by the actual performance of the instrument.

* Jones. Elec. Tel., New York, 1852, p. 112.

239. Although the distance to which the dispatch has to be sent cannot be said directly to affect the celerity of transmission, there are circumstances nevertheless which in practice render the transmission to great, slower than to lesser distances. In Europe, for example, stations separated by great distances, are generally in different countries, and the telegraphic line which connects them often passes through several different states in which different telegraphic systems are used, and where it is not practicable to put the wires proceeding from one direction in immediate connection with those which proceed in another. In such cases the messages which arrive must be taken down and retransmitted in the direction in which they are intended to be forwarded, and on this account alone, the time of transmission is augmented, at least in the ratio of the number of such repetitions which are necessary. But besides this, it rarely happens that a message on arriving at such intermediate station can be at once forwarded. It must wait its turn unless the wires happen to be unoccupied.

And even though it may be practicable to establish a direct communication between two distant stations by putting the wires in immediate connection, more or less delay must necessarily take place. The telegraphist who transmits, must first send a message along the line to all the intermediate stations to require the wires to be united for direct communication. At these intermediate stations, the wires may be employed, and the message must wait until they are free.

Thus, although it be true that so far as the electric fluid and the apparatus by which it is transmitted are concerned, they are capable of sending a message from pole to pole in an inappreciable interval, yet the machinery of telegraphy as practically constructed presents causes of delay which prevent in many cases this vast celerity from being called into action.

Until very recently, a message transmitted from Milan to Paris, being necessarily sent round by Trieste, Vienna, Berlin, and Brussels, was more than twenty-four hours in reaching its destination.

Besides these causes of delay, there are, however, others. It has been stated that the intensity of the current is diminished, *ceteris paribus*, as the distance is augmented. When transmission therefore to great distances is required, various expedients, at intermediate stations, such as relay batteries or relay magnets, or both, are required, and notice must be given to apply these even when they are provided.

The chances of interruption by reason of defective insulation or accidents to the wires, are also increased in proportion to the distance.

240. As may be naturally expected, the most frequent examples of direct telegraphic communication to great distances are supplied by the United States.

On the lines of the O'Reilly Company of New York,* messages are daily transmitted without any intermediate repetition to a distance of 1100 miles, that is from New York to Louisville in Kentucky.

"To do this, it is found necessary to place two batteries in the circuit at a distance of 400 miles apart, for the purpose of renewing the electric current, part of which escapes from defective insulation and atmospheric causes. There is no doubt but that, in a more advanced stage of telegraphing—which may be but a short time hence—New Orleans and New York will be placed in instantaneous communication with each other. To enable this to take place, requires, in the first place, a line substantially built and thoroughly insulated. It may be remarked, that it is but two years since, when to telegraph 300 miles on a single or unbroken circuit, was considered a feat; now, from improvements made since then in telegraphs, we can send over 1100 miles easier than we could 300 at that time. In our Cincinnati office, two years ago, and until very lately, they used a separate battery for each line. From a series of experiments made, one single battery, of no greater strength than those formerly used, now works eight distinct and separate lines, with no apparent diminution of strength, and at a great saving of expense to the office." †

A report of the directors of the New York Bain lines states that messages are transmitted by them, without being rewritten, from New York to Buffalo, a distance of 500 miles. This is done without any intermediate relay batteries or magnets.

The directors of the Morse lines at New York report that their telegraph messages have in some cases been actually transmitted without intermediate repetition to a distance of 1500 miles.

241. The promptitude with which dispatches are expedited, and the celerity with which they are transmitted, will be greatly promoted in all cases by an uniform system and organisation being established upon the lines over which they are transmitted. No greater cause of delay can exist than that which arises from diversity of telegraphic instruments and language. Much

* The American Telegraph Companies are subject to such constant changes, that it may be necessary to state here, once for all, that the names and denominations to which we refer are those which were current in 1853-4, but which may be changed before these sheets come into the hands of the reader.

† *Report* of Mr. O'Reilly. Jones's El. Tel., p. 101.

inconvenience, expense, and delay also arise even in cases where similar instruments and ciphers are used, from a want of uniformity in the various parts of the apparatus, and in the systems of abridgments which are adopted in the language. Where tho instruments and the parts of apparatus have been constructed of varying patterns and sizes, they cannot be readily replaced in cases of wearing out or accidental fracture. By the adoption of one uniform size and pattern, depots of all the parts may be provided, from which any station which may be stopped by an accident can be immediately supplied with the part or parts which require to be replaced. Another advantage incidental to such uniformity is greater economy in the maintenance of the apparatus and lines.

Impressed with these considerations, a large majority of the American telegraph companies have formed themselves into a confederation, which meets annually at Washington, and which is permanently represented there by a permanent committee and secretary.

This body has published reports containing many important and interesting statistical facts, and has adopted measures with a view to the establishment of a central depôt for the supply of all articles necessary for the maintenance of the lines and stations, of good quality and at fair prices. The secretary of the convention, Mr. J. P. Shaffner, has commenced the publication of a monthly periodical devoted to subjects directly and indirectly connected with electric telegraphs; and as not less than nine-tenths of all the American lines, as well as those of contiguous states, are worked with Morse's instrument, it is proposed to reduce it as speedily as possible to one uniform pattern, so that its parts, as well as those of the batteries, may be always ready to be supplied in cases of failure or breakage, the like parts fitting indifferently all instruments and all apparatus.

The batteries invariably used by the American telegraphs are those of Grove, each element of which consists of a cup of unglazed earthenware, placed in a glass tumbler of equal height and greater diameter. A zinc cylinder is let down between the glass and the earthenware cup, and a platinum cylinder is let down into the earthenware cup. The space between the cups is then filled with acidulated water, and the earthenware cup is filled with pure nitric acid.

Such being the batteries, the articles of consumption in the working of the telegraphs are enumerated as follows by the secretary of the convention:—Nitric and sulphuric acids, zinc, quicksilver (for amalgamating the zinc, &c.), skeleton forms for messages, ink, envelopes, pencils, and pens.

From statistical data collected by the secretary, it was found that in 1853 the annual consumption and cost of these materials was as follows:—

	Quantities.	Cost.
Nitric acid	199680 lb.	£1105
Sulphuric acid	50000 lb.	500
Zinc cylinders	16500 lb.	400
Mercury	3000 lb.	600
Forms for messages . . .	10,000000	5000
Envelopes	6,000000	2680
Pens	576000	720
Pencils	50000	500

These returns, including only the results of the lines worked by the Morse instruments, about nine-tenths of the whole, would require to be increased by a ninth to obtain the total consumption.

It appears, therefore, that on the lines of the United States, the number of telegraphic messages transmitted in 1853 exceeded ELEVEN MILLIONS!

THE USES OF THE ELECTRIC TELEGRAPH.

242. To form an estimate of the uses to which the electric telegraph subserves, it would be necessary to obtain a report of the subjects of the messages classified, with the relative number of each class, which are transmitted from and received by the chief telegraphic stations. Although we have not been able to procure to any great extent such data, some notion may be collected as to the way in which this new social, commercial, and political agent is employed, from such scattered statements and notices as we have been enabled to collect from various sources.

It appears that the prevailing subjects of the dispatches vary according to the station from or to which they are sent. Thus, as might naturally be expected, in large commercial marts, such as Liverpool and Glasgow, they are chiefly engrossed by messages of mercantile firms and business. Their prevailing subjects also vary much with the season of the year. Thus, in summer, the messages of tradesmen are greatly multiplied in consequence of the number transmitted by dealers in perishable articles, such as fish, fruit, &c., which must be supplied in regulated quantities with the greatest promptitude.

We have obtained from the manager of the English and Irish magnetic telegraph company, the following classification of

nearly 5000 dispatches which passed through the Liverpool office in the early part of the present year, 1854.

General merchants	1954
Stock and share transactions	1441
Ship insurers, brokers, &c.	339
Banking messages	315
Corn dealers	272
Betting	233
Personal and domestic	201
General brokers	117
Tradesmen	50
Cotton brokers, &c.	34
Law	31
Political	6
	4993

243. Mr. Walker gives the following list of the subjects of dispatches sent through the office of the Electric Telegraph Company, as a specimen of the uses which the public make of this mode of communication.

Accidents	Customs	Markets	Post-horses, &c.
Announcements	Deaths	Medical aid	Reporters
Appointments	Departures	Meteorology	Remittances
Arrivals	Dispatches	Missing trains	Respite
Arrests	Elections	Murders	Robberies
Bankers	Elopements	News	Royal movements
Beds	Expresses	Nurses	Sentences
Bills	Funds and Shares	Orders	Shipping news
Births	Government	Passengers	Ship-stores
Commotions	Health	Payments	Turf
Counsel	Hotels	Police	Witnesses
Couriers	Judgments	Political	Wrecks
Corps	Lost luggage		

It is obvious that the uses, whether personal or commercial, of the telegraph, are restricted by the tariff, and by the necessity of disclosing the contents of the dispatches to the telegraph agents. In England, the latter obstacle may in some cases be surmounted by the use of a cipher. The cipher must, however, always consist of a transposition of the letters, since the telegraphic signs only express letters, and besides this, it can never be used on sudden emergencies, inasmuch as it supposes a previous concert between the corresponding parties.

244. The obstacle to the extension of the uses of the telegraph, created by the tariff, has been of late greatly lessened by the considerable reduction of the prices of transmission, and it may be hoped that ere long the companies and the public will discover that the interest of the one and the convenience of the other will

be best promoted by a still further reduction of price, and a still larger use of this mode of intercommunication.

It is probable and desirable that something approaching to the uniform postage system may eventually be realised in the telegraph. Already a certain step towards such a system has been made, since for a fixed sum messages of a prescribed length can be transmitted to all distances exceeding a certain limit.

In the absence of exact statistical reports of telegraphic business, it may not be uninteresting to give some examples of the uses of this mode of communication.

245. In the management of railway business in all countries, but more especially upon our own ever crowded and over-worked lines, the telegraph has become an indispensable accessory, without which this mode of locomotion would be deprived not only of its efficiency but its safety. Consequently the railways in most countries have been provided with lines of telegraph expressly and exclusively for their own use, independently of those which are appropriated to the public service; and on the continent such telegraphs are usually alphabetic, that is, such as convey their messages by pointers, which are successively directed to the letters of the words, so that any of the railway officials who can read, may be able to interpret a message which arrives, or to transmit one to a distant station.

To illustrate the vast utility of the telegraph to the railway, Mr. Walker states that on the lines of the South Eastern Company, in the space of three months, upwards of 4000 messages have been occasionally transmitted, being at the average rate of nearly 50 per day. He gives the following as a rough classification of their subjects—

			Messages.
1.	Concerning	ordinary trains.	1468
2.	,,	Special trains	429
3.	,,	Carriages, trucks, goods, sheets, &c.	795
4.	,,	Company's servants	607
5.	,,	Engines	150
6.	,,	Miscellaneous matters	162
7.	,,	Messages forwarded to other stations .	499
		Total	4110

246. It has been already stated that portable telegraphs are provided in some parts of the continent, and in France in particular, with which the conductors are provided. Such telegraphs have also been contrived in this country, but we are not aware of their practical adoption. By these the conductor of a train can, whenever the train is stopped between stations, whether from accident or other

cause, give immediate notice to the preceding and succeeding stations, so as to prevent a collision by a following train overtaking that which is accidentally stopped, or if necessary he can call for an engine to carry on the train, or any other aid that may be required.

247. Notices of the passing, starting, and arrival of trains are however transmitted from station to station, quite independent of any accidents that may arise, so that all the station-masters, so far as relates to the movement upon the line, are endowed with a sort of omnipresence; so conscious are they of the possession of this power and its value, that their language is that of persons who actually *see* what is going on at vast distances from them. Thus, as Mr. Walker observes, they are in the common habit of saying—"I just saw the train pass such or such a station," fifty miles distant perhaps, when in reality all he saw was the deflection of the needle of their telegraph.

"If trains are late, the cause is known; if they are in distress, help is soon at hand: if they are heavy, and progress but slowly, they ask and have more locomotive power either sent to them or prepared against their arrival; if there is anything unusual on the line they are forewarned of it, and so forearmed; if overdue, the old plan of sending an engine to look after them has become obsolete—a few deflections of the needle obtain all the information that is required." *

The utility of special trains is well known. News of the utmost importance, or a government courier bearing dispatches of the greatest urgency arrives at one of our ports and demands a train *instantly* to convey him to London. Now in such cases it does not often happen that a disposable engine is found at the station where the demand is presented; but the telegraph sends a dispatch along the line, calling one from the nearest station at which one can be found, and when the engine has been obtained the special cannot start with safety unless the line is cleared for it.

The telegraph again interposes its aid, and sends a notice along the line of the moment of starting, from which, combined with the known speed of the train, the exact moment when it will pass every station upon the line is known, and of course the line is cleared for it, and all danger of collision removed. How frequent are the occasions for appealing to the telegraph for this aid without which special trains would not only be less rapid, but infinitely less safe, as well for themselves as others, may be seen by reference to the analysis of dispatches we have given above, from which it appears that in three months, upon the South-

* Walker, p. 84.

Eastern lines, there were not less than 429 messages respecting special trains, that is at the rate of about five per day.

248. In the general management of the traffic upon an active line of railway, an incalculable amount of capital and current expenditure is saved by the telegraph. Without it rolling stock would require to be provided in much greater quantity, and a far greater unprofitable wear and tear by useless trips, of what in railway language are called "empties," would take place. By the telegraph, as we have stated, each station-master is ubiquitous so far as the line is concerned. He knows where carriages, waggons, trucks, sheets, and engines are to be found, and how many of them, and he calls by the telegraph so many, and no more than he wants, and at the time he wants them, from the nearest or most convenient station where they are to be obtained.

Before the establishment of the telegraph, some of these objects were imperfectly attained by means of pilot engines, that is engines taking no vehicle, which habitually run along the line to carry messages from station to station. As an evidence of the immense saving effected by the telegraph in the practical working of railways, Mr. Walker states, that the cost of maintaining and working a single one of those pilot engines, (all of which have been superseded by the telegraph,) amounted to a greater sum than is now required to defray the expense of the entire staff of telegraph clerks, and the mechanics and labourers employed in cleaning and repairing the instruments and maintaining the integrity of the line wires.

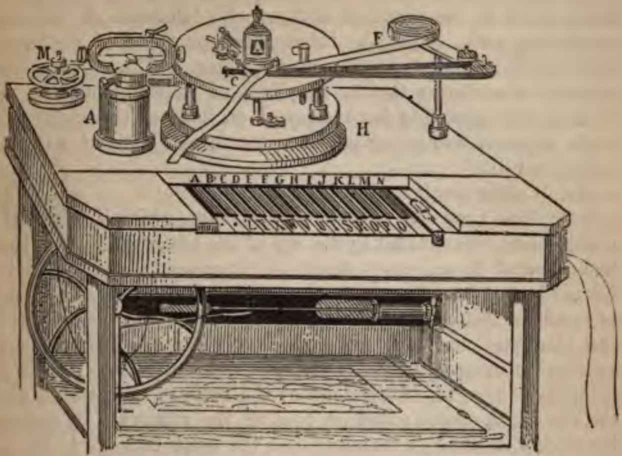


Fig. 89 —HOUSE'S TELEGRAPH.

THE ELECTRIC TELEGRAPH.

CHAPTER XII.

249. Prevention of accidents.—250. Its uses in the detection of crime.—251. Personal and domestic messages.—252. Electric news-rooms.—253. Telegraph extensively used in the United States.—254. Much used for commerce.—255. Sums paid for telegraphic despatches by mercantile firms.—256. Extensively used by American newspapers.—257. Illustration of the utility for political purposes.—258. Illustrations of its domestic and general use.—259. Secrecy of despatches not generally sought for.—260. Verbal ciphers of mercantile firms.—261. Ciphers for newspaper reports.—262. Association of New York journals.—263. Spirited enterprise of New York "Herald."—264. Use of electric telegraph in determining longitudes.—265. In producing horological uniformity.

249. AMONG the serious railway accidents which might have been, or actually were prevented by the telegraph, the following have been mentioned :—

In a storm, the wind blew a first-class railway carriage, which

stood in an open shed at a second-class station, and putting it in motion upon a very level line, sent it flying with accelerated speed to the terminal station. No telegraph at that time existed to warn either the intermediate or terminal stations of the event and the approaching danger. The vehicle was actually *blown* over twenty-one lines of railway, but the trip it thus took occurring fortunately at an hour of the night when little business was going on, it came to rest without any calamitous result.

Mr. Walker mentions the following:—

"On New Year's Day, 1850, a catastrophe, which it is fearful to contemplate, was averted by the aid of the telegraph. A collision had occurred to an empty train at Gravesend; and the driver having leaped from his engine, the latter started alone at full speed to London. Notice was immediately given by telegraph to London and other stations; and while the line was kept clear, an engine and other arrangements were prepared as a buttress to receive the runaway. The superintendent of the railway also started down the line on an engine; and on passing the runaway, he reversed his engine and had it transferred at the next crossing to the up-line, so as to be in the rear of the fugitive; he then started in chase, and on overtaking the other, he ran into it at speed, and the driver of his engine took possession of the fugitive, and all danger was at an end. Twelve stations were passed in safety: it passed Woolwich at fifteen miles an hour: it was within a couple of miles of London before it was arrested. Had its approach been unknown, the mere money value of the damage it would have caused might have equalled the cost of the whole line of telegraphs. They have thus paid, or in a large part paid, for their erection.

"As a contrast to this, an engine, some months previously, started from New Cross toward London. The Brighton Company have no telegraphs; and its approach could not be made known. Providentially, the arrival platform was clear; it ran in, carrying the fixed buffer before it, and knocked down, with frightful violence, the wall of the parcels office."

250. Among the general uses of the telegraph to the public, many examples of the detection of crime are mentioned. It is generally known that the notorious Tawell, after the commission of the murder, started for London from Slough, by the Great Western Railway. Notice of the crime, and a description of his person, however, flew with the speed of light along the wires and arrived at Paddington so much earlier than the murderer himself, that upon his arrival he was recognised, tracked

om place to place, finally apprehended, tried, convicted, and xecuted.

One night at ten o'clock, the chief cashier of the bank received notice from Liverpool, by electric telegraph, to stop certain notes. The next morning the descriptions were placed upon a card and given to the proper officer, to watch that no person exchanged them for gold. Within ten minutes they were presented at the counter by an apparent foreigner, who pretended not to speak a word of English. A clerk in the office who spoke German interrogated him, when he declared that he had received them on the Exchange at Antwerp six weeks before. Upon reference to the books, however, it appeared that the notes had only been issued from the bank about fourteen days, and therefore he was at once detected as the utterer of a falsehood. The terrible Forrester was sent for, who forthwith locked him up, and the notes were detained. A letter was at once written to Liverpool, and the real owner of the notes came up to town on Monday morning. He stated that he was about to sail for America, and that whilst at an hotel he had exhibited the notes. The person in custody advised him to stow the valuables in his portmanteau, as Liverpool was a very dangerous place for a man to walk about with so much money in his pocket. The owner of the property had no sooner left the house than his adviser broke open the portmanteau and stole the property. The thief was taken to the Mansion-House, and could not make any defence. The sessions were then going on at the Old Bailey. Though no one who attends that court can doubt that impartial justice and leniency are administered to the prisoners, yet there is no one who does not marvel at the truly railway-speed with which the trials are conducted. By a little after ten the next morning—such was the speed—not only was a true bill found, but the trial by petty-jury was concluded, and the thief sentenced to expiate his offence by ten years' exile from his native country.

I take the following illustration of this from a recent article on the subject which appeared in the "Quarterly Review."

The following is extracted from the telegraph book preserved at the Paddington station:—

"Paddington, 10.20 A.M.—'Mail train just started. It contains three thieves, named Sparrow, Burrell, and Spurgeon, in the first compartment of the fourth first-class carriage.'

"Slough, 10.48 A.M.—'Mail train arrived. *The officers have cautioned the three thieves.*'

"Paddington, 10.50 A.M.—'Special train just left. It contained two thieves: one named Oliver Martin, who is dressed in black, *crape on his hat;* the other named Fiddler Dick, in black trousers

and light blouse. Both in the third compartment of the first second-class carriage."

"Slough, 11.16 A.M.—'Special train arrived. Officers have taken the two thieves into custody, a lady having lost her bag, containing a purse with two sovereigns and some silver in it; one of the sovereigns was sworn to by the lady as having been her property. It was found in Fiddler Dick's watch-fob.'

"It appears that, on the arrival of the train, a policeman opened the door of the 'third compartment of the first second-class carriage,' and asked the passengers if they had missed anything? A search in pockets and bags accordingly ensued, until one lady called out that her purse was gone. 'Fiddler Dick, you are wanted,' was the immediate demand of the police-officer beckoning to the culprit, who came out of the carriage thunderstruck at the discovery, and gave himself up, together with the booty, with the air of a completely beaten man. The effect of the capture so cleverly brought about is thus spoken of in the telegraph book:—

"Slough, 11.51 A.M.—'Several of the suspected persons who came by the various down-trains are lurking about Slough, uttering bitter invectives against the telegraph. Not one of those cautioned has ventured to proceed to the Montem.'

"Ever after this the light-fingered gentry avoided the railway and the *too* intelligent companion that ran beside it, and betook themselves again to the road—a retrograde step, to which on all great public occasions they continue to adhere."*

251. One of the consequences of the high price of transmission is that personal and domestic messages are most generally confined to cases of urgency, and often of distress, painful or ludicrous, as the case may be. Persons in easy circumstances, it is true, often resort to the telegraph to gratify a caprice or to obtain some object of gratification for which they are impatient. The mixture of subjects which the agents in rapid succession read from the needles, is most curious. "We have," says Mr. Walker, "ordered a turbot, and also a coffin; a dinner, and a physician; a monthly nurse, and a shooting-jacket; a special engine, and a chain-cable; an officer's uniform, and some Wenham-lake ice; a clergyman, and a counsellor's wig; a royal standard, and a hamper of wine; and so on. Passing over the black leather bag which some one every day appears to leave in some train, passengers have recovered luggage of most miscellaneous character by means of the telegraph.

* Quarterly Review, No. CLXXXIX., p. 129.

In the trains have been left a pair of spectacles, and a pig; an umbrella, and *Layard's Nineveh;* a purse, and a barrel of oysters; a great-coat, and a baby; and boxes and trunks, *et id genus omne*, without number."

252. Independently of the direct use made of the electric telegraph by the general public, for the transmission of private despatches, the several companies have established, in various principal places, news rooms, where intelligence is from hour to hour posted, as it arrives from all parts of the world.

The Electric Telegraph Company, soon after its establishment, opened subscription news rooms in the chief towns of England, especially those of the northern counties, in which intelligence of every description which could interest the general public was posted from hour to hour during the day, immediately on its transmission from London. These establishments did not, however, receive the necessary public support, and with one or two exceptions they have been discontinued. There is, however, in the Lothbury establishment, besides the private message department, a general intelligence office, in which the news published in the morning journals is condensed and transmitted to the exchanges of Liverpool, Bristol, Manchester, Glasgow, and other chief provincial centres of business.

On the evenings of Fridays, the London news is collected, condensed, and transmitted to the offices of upwards of 120 provincial Saturday papers, which thus receive during the night before their publication the most recent intelligence of every sort received by telegraph from all parts of Europe besides the current news of London to the latest moment. An example of the extraordinary efficiency of this department is given in the case of one of the Glasgow Saturday journals, which often receives as much as three columns of the debates, transmitted while the Houses are still sitting. A superintendent and four clerks are exclusively engaged in the business of this department, and in the latter days of the week their office presents all the appearances of the editor's room of a widely circulating journal. "At seven in the morning the clerks are to be seen deep in 'The Times' and other daily papers, just hot from the press, making extracts and condensing into short paragraphs all the most important news, which are immediately transmitted to the country papers to form second editions. Neither does the work cease here, for no sooner is a second edition published in London than its news, if of more than ordinary interest, is transmitted to the provinces." Arrived at the chief places in direct communication with London "swifter than a rocket *could fly* the distance, like a rocket it bursts and is

again carried by diverging (branch) wires into a dozen neighbouring towns" of less magnitude and importance.*

Besides this organisation for the general transmission of despatches from one quarter of the great metropolis to another, there are some curious special arrangements made for the satisfaction of the wants of particular classes. Thus a wire is exclusively appropriated to communications between the Octagon Hall of the Houses of Parliament and the telegraphic station in St. James-street, the centre of the West-end clubs. This particular wire should be called the "'whipper-in' of the House, for it is nothing more than a call-wire for members. The company employ reporters during the sitting of Parliament to make an abstract from the gallery of the business of the two Houses as it proceeds, and this abstract is forwarded at very short intervals to the office in St. James's-street, where *it is set up and printed,* additions being made to the sheet issued as the MS. comes in. This flying sheet is sent half-hourly to the following clubs and establishments:—Arthur's; Carlton; Oxford and Cambridge; Brookes's; Conservative; United Service; Athenæum; Reform; Travellers'; United University; Union; and White's. Hourly to Boodle's Club and Prince's Club; and half-hourly to the Royal Italian Opera. The shortest possible abstract is of course supplied, just sufficient in fact to enable the after-dinner M.P. so to economise his proceedings as to be able to finish his claret and yet be in time for the ministerial statement, or to count in the division. The following, for instance, is a fac-simile of the printed abstract of the debate on the Address to her Majesty on the declaration of war:—

THE ELECTRIC TELEGRAPH COMPANY.

(INCORPORATED 1846.)

HOUSE OF COMMONS, FRIDAY, MARCH 31ST, 1854.

TIME. H.	M.		REMARKS.
4	0	House made.	HOUSE OF LORDS.
4	30	Private business and Petitions.	Lord Aberdeen stated, in
4	40	Mr. Napier brought up report of Dungarvan Election Committee: Maguire duly elected, and attention called to state of law upon the withdrawal of Petitions.	reply to Lord Roden, that it was intended to appoint a day for solemn prayer for a blessing on
5	0	Notices.	Her Majesty's arms by
5	30	Lord John Russell moving reply to message of Her Majesty.	sea and land. Earl of Clarendon moved

* Quarterly Review, No. CLXXXIX., p. 138.

TIME.			REMARKS.
H.	M.		
6	0	Stating various transactions and negotiations which have taken place with Russia.	the address in reply to the Queen's message. Earl of Derby: observations.
6	30	Mr. Layard approved of the sentiments expressed.	(7 · 30). Earl of Aberdeen
7	0	Still speaking.	replied to Lord Derby.
7	30	Compared the language and opinions of different Members of the Cabinet, and called attention to various articles in the "Times," which he maintained to be written with a full knowledge of the contents of the secret and confidential correspondence.	(7 · 45). Earl of Malmesbury regretted the tone taken by the Prime Minister. (8 · 20). Earl Granville: observations. Lord Brougham ditto.
8	0	Mr. Bright replied to Mr. Layard, adverse to policy of the Government.	Earl Grey ditto. (8 · 50). Earl of Hard-
8	30	Still speaking.	wicke wished for a
9	0	Still speaking.	larger Naval Reserve.
9	30	Mr. J. Ball was prepared to support the war, though not agreeing in the reasons put forward to justify it.	(8 · 55). Marquis of Lansdowne said it was necessary to check Russia.
10	0	The Marquis of Granby expressed his regret at the language used by certain members of the Government with respect to the Emperor of Russia, whose conduct regarding Turkey he vindicated. Lord Dudley Stuart.	(9 · 5). Address agreed to, to be presented on Monday. LORDS ADJOURNED, 9 · 25.
10	30	Still speaking.	
11	0	Lord Palmerston vindicating the policy of the Government.	
11	30	Mr. Disraeli supported the address, but severely criticised the conduct of different Members of the Cabinet.	
12	0	Analysing the secret and confidential correspondence to show that a plan for the partition of Turkey was assented to by the English Government in 1844, when the Earl of Aberdeen was Secretary for Foreign Affairs.	
12	30	Lord John Russell replying to Mr. Layard, and the observations of other speakers.	
12	40	Colonel Sibthorp: observations. The Address to Her Majesty agreed to: and on the motion of Lord John Russell, and seconded by Mr. Disraeli, to be presented by the whole House.	
1	0	HOUSE ADJOURNED.	

Saint James's Street Branch Station, No. 89, at the End of Pall Mall, opposite Saint James's Palace.

"The wire to the Opera is a still more curious example of the social services the new power is destined to perform. An abstract of the proceedings of Parliament similar to the above, but in *writing*, is posted during the performance in the Lobby, and Young England has only to lounge out between the acts to know if Disraeli or Lord John Russell is up, and whether he may sit out the piece, or must hasten down to Westminster. The Opera-house even communicates with the Strand-office, so that messages may be sent from thence to all parts of the kingdom. The government wires go from Somerset-house to the Admiralty, and thence to Portsmouth and Plymouth by the South-Western and Great Western Railways; and these two establishments will shortly be put in communication, by means of subterranean lines, with the naval establishments at Deptford, Woolwich, Chatham, Sheerness, and with the Cinque Ports of Deal and Dover. They are worked quite independently of the company, and the messages are sent in cipher, the meaning of which is unknown even to the telegraphic clerks employed in transmitting it. In addition to the wires already spoken of, street branches run from Buckingham Palace and Scotland Yard (the head police-office) to the station at Charing-cross, and thence on to Founder's-Court; whilst the Post-office, Lloyd's, Capel-court, and the Corn Exchange communicate directly with the central office." *

The Magnetic Telegraph Company have made arrangements by which the correspondents of the press are allowed to forward messages upon an entirely different basis; the charge for intelligence so transmitted, amounting to only one-tenth of the charge to the public, the matter being more voluminous, and passing through the wires at a time when they are not otherwise occupied.

The company also supplies the press and news-rooms in various parts of the United Kingdom, and especially throughout Ireland, with news by *contract;* at the rate of about one halfpenny per line of ten words; and are enabled to do so, by making manifold copies of the information (whatever be its nature) for the use of *all* the press, &c., in each town or district, through which such news passes.

Under such arrangements, intelligence to the amount of two closely printed newspaper columns, or more, daily, is transmitted between all the stations, conveying information of the various share, corn, cotton, coal, iron, cattle, provision, and produce markets; fairs, shipping arrivals, foreign and domestic information, Gazette news, Parliamentary reports, &c., &c. Each piece of news, whatever its nature, obtained in *one* town being conveyed

* Quarterly Review, No. CLXXXIX., pp. 139—141.

to *all* the rest; the arrival of vessels in Queenstown, the result of a market in Cork, or of a cattle fair at Ballinasloe, affording intelligence for the whole of the United Kingdom, and *vice versá.*

In order to carry out this system, the company employs paid agents, news collectors, parliamentary reporters, &c.

253. It is a fact well known that the electric telegraph is much more extensively used for all purposes, political, commercial, and domestic, in the United States, than in this or any other part of Europe. Before the reductions which have within the last year or two taken place in the tariffs, this might fairly be explained by the comparatively small cost of transmission in America. But since those reductions were effected, it may be questioned whether there is any difference of cost sufficiently considerable to explain the vast difference in the extent to which the public, on different sides of the Atlantic, avail themselves of this mode of inter-communication.

We shall notice the question of the tariffs hereafter. Meanwhile, whatever be the cause, it is certain, that the practical use of the telegraph is much more extended among our transatlantic descendants.

The tariffs vary on different lines, but it has been estimated that the cost of a message of 10 words, exclusive of address and signature, sent 10 miles, is about *5d.*, and for greater distances the cost may be taken at about 0·035*d.* per word per mile.

The classes of messages entitled to precedence, are government messages, and messages for the furtherance of justice in detection of criminals, &c. ; then death messages, which includes cases of sickness when the presence of a party is sent for by the sick and dying. Important press-news comes next; if not of extraordinary interest, it takes its turn with the mercantile messages.

254. Commercial houses resort largely to the telegraph. For example: a person purchasing goods in New York, gives his reference to the merchant—such reference being perhaps 700 or 800 miles away from him. By the aid of the telegraph the merchant can learn the standing of his customer, even before the purchase is completed. There are bankers, brokers, &c., that receive and send, on an average, six to ten messages per day, throughout the year.

255. The manager of House's line at New York states that some commercial houses pay to the company as much as 200*l.* a-year, and that the average annual receipts from twenty mercantile houses amount to 100*l.* each.

The directors of Bain's New York lines report that the telegraph is used by commercial men to almost as great an extent as the mail. This can be better illustrated by the number of messages sent and received between cities whose commercial relations are

intimate, during the hours from 10 A.M. to 5 P.M. For instance: there are transmitted daily, between the cities of New York and Boston, between 500 and 600 messages, two-thirds if not three-fourths of which are transmitted between the hours above named. Some houses pay from 12*l.* to 16*l.* per month to the telegraph. The amount paid by a commercial house is governed by the excitement there is in the market of the particular article they may be dealing in. If there are "ups and downs" in the market, money is lavished upon the telegraph freely.

The directors of the Morse New York lines, state that the annual telegraph outlay of several houses amounts to 600*l.*

It often happens that a party desires to "converse" with another 400 or 500 miles off. An hour is appointed to meet in the respective offices, and they converse through the operator. Cases may be mentioned of steamboats being sold over the wires —the one party being in Pittsburg, the other in Cincinnati. Each party wrote down what they had to say, higgled awhile, and finally concluded the sale. Their correspondence was filed away, like other messages, and kept for reference, if ever called in question. It is often used by parties, when from home, corresponding with their families. Sometimes it is the messenger of woe; and anon, that of pleasure. In the early part of 1852, the Astor House of New York, and the Burnet House of Cincinnati, had a series of telegraphic parties. An account of one of them was published in the "Cincinnati Gazette," the parties conversing being about 750 miles apart.

256. The following example of the activity of journalism is given by Mr. Jones, who was himself a telegraphic agent for the newspapers:—"Some time back the Asia arrived at Quarantine, near New York, about 8 P.M., was detained an hour by the health officer. The agent of the New York Associated Press and of the New Orleans Merchants' Exchange, Mr. Jones, to gain but a few minutes, had a boat in readiness when the Asia brought to. A small bag containing the latest news was handed over the steamer's side, to the small boat. By great exertions she gained New York half an hour ahead of the Asia. The bag was opened—a copy of her news was handed to us, addressed to the Merchants' Exchange, New Orleans, signed *Jones*—to work we went. It was being transmitted over the wires amid the thundering of the Asia's cannon, as she rounded the point; and a complete synopsis of her commercial and political news was received in Louisville, 1100 miles in the interior, before the ship had actually reached the city."

The managers of the Morse line at New York state that, *during* the sittings of conventions, or elections, or the arrival of

steamers, often from 2000 to 8000 words are reported. On some occasions of market excitement, the private messages are nearly doubled.

Debates of Congress are received at an average of about 4500 words per day, and transmitted at the rate of 1600 words per hour.

On the assembly of the Legislature of the State of New York at Albany, in 1847, the governor's message, consisting of 25000 letters, was transmitted to New York, 150 miles, and printed by the telegraph itself in two hours and a half.

257. In his reports to Congress, Mr. Morse has supplied various examples of the use made of the telegraph by all classes of persons. During the Philadelphia riots of 1844, the mayor of that city sent an express by railway, to the President of the United States at Washington. On the arrival of the train at Baltimore, the contents of the express transpired, and the telegraph, which was then just put in operation between Baltimore and Washington, not being yet established elsewhere in the States, sent on the substance of the despatch. The President held a cabinet council while the despatch itself was coming, and had his answer prepared and delivered to the messenger who brought the despatch at the moment of his arrival, who returned with it instantly to Philadelphia.

258. Nothing is more frequent in the United States than electric medical consultations. A patient in or near a country village desires to consult a leading medical practitioner in a chief city, such as New York or Philadelphia, at four or five hundred miles distant. With the aid of the local apothecary, or without it, he draws up a short statement of his case, sends it along the wires, and in an hour or two receives the advice he seeks, and a prescription. Cases are recorded in which electric marriages have been contracted between parties separated one from another by many degrees of latitude. A correspondent of the author of a paper in Chambers's Collection states, that in the United States, "The telegraph is used by all classes, except the very poorest—the same as the mail. A man leaves his family for a week or a month; he telegraphs them of his health and whereabouts from time to time. If returning home, on reaching Albany or Philadelphia, he sends word of the hour that he will arrive. In the towns about New York the most ordinary messages are sent in this way: a joke, an invitation to a party, an inquiry about health, &c. In our business we use it continually. The other day two different men from Montreal wanted credit, and had no references; we said: 'Very well; look out the goods, and we will see about it.' Meanwhile we asked our friends in Montreal—'Are Pump and Proser good for one hundred dollars each?' The

answer was immediately returned, and we acted accordingly; probably much to our customers' surprise. The charge was a dollar for each message, distance about 500 miles, but much further by telegraph, as it has to go a round to avoid water. If my brother goes to Philadelphia, he telegraphs, 'How is the family? What is doing?'—I answer, 'All well. Sales so much,' and so on." *

It has been contended by some, with much reason, that one of the most serious drawbacks to the general extension of the use of the electric telegraph is the impracticability of preserving that secrecy which the seal confers on written correspondence, the absence of which would utterly annihilate the utility of the post-office. The imperious necessity of guarding this secrecy inviolate is apparent in the heavy penalties attached to the rupture of the seal, which can only be effected with impunity by a special authorisation of a secretary of state. To confer on the electric telegraph all the public utility of which it is susceptible, means must be adopted, and will, no doubt, be ultimately adopted for the attainment of this object, the vital importance of which is implicitly acknowledged by the heavy penalties, the smallest of which is dismissal, imposed in all countries on the agents who disclose the contents of private telegraphic correspondence.

Such expedients must nevertheless be ineffectual, for it would contradict all the results of the common experience of life, if what must inevitably be communicated to half a dozen persons at least, and a copy of which is retained and filed in a public office, could remain secret from any parties who might have a sufficiently strong motive to come to the knowledge of it. But even though the disclosure of private communications to parties not employed in the telegraphic offices should be effectually prevented by the present expedient of swearing the clerks to secrecy, and inflicting the consequent penalties for the violation of their oath, still individuals communicating in private confidence one to another, wives to husbands, sisters to brothers, or children to parents, have things to say which it would be utterly intolerable, as is most justly observed by the reviewer already quoted even "to *see* strangers read before their eyes. This is a grievous fault in the telegraph, and it must sooner or later be remedied by some means or other."

The object might be accomplished by the use of any species of cipher, but this supposes that the parties corresponding have previously prepared the cipher, and are mutually possessed of its key. Such a condition could only be practically fulfilled by

* "Chambers's Papers for the People," vol. ix. No. 71.

correspondents having habitual need of intercommunication, such as mercantile establishments interchanging news of the markets, stocks, sales, and other commercial details; but for the occasional communications of domestic life it would be quite unavailable.

It is hinted by 'the Quarterly Reviewer,' that Mr. Wheatstone has invented a cipher which will be applicable to general purposes, and which will attain this object, and that it will be soon placed at the disposition of the public.

If the same privacy as is afforded by the post-office can be thus secured to telegraphic communications, and if by the multiplication of their wires, and the improved efficiency of their instruments, the companies are enabled to reduce their tariff to a still lower limit, and to base it on some uniform principle similar to the admirable penny postage system of Mr. Rowland Hill, it is difficult to foresee the extent of the revolution which this noble gift of science to mankind may effect. Great as the benefits have been which the post-office has conferred, they will sink to nothing compared with those of the telegraph. In estimating the importance of the part reserved for this vast agent of civilisation, it must not be forgotten that it is still in its early infancy, and that its most wondrous powers are not yet developed by time and growth.

259. The necessity of disclosing the contents of private despatches to the telegraphists is sometimes avoided in the United States by the adoption of a cipher, or by a conventional change of the signification of the letters of the alphabet. In some cases, with the telegraph of House, the manipulation of which is easy and simple, the party plays upon the keys of the instrument himself. It is, however, only in rare instances that these expedients are resorted to. The public confidence has been won by the general secrecy observed by the telegraphic agents, and in general no apprehension of disclosure prevents persons from sending the most private and confidential despatches in the usual manner. One of the directors, who for four years has had the superintendence of extensive lines, states, that in that interval he never heard of an instance of the contents of a despatch being divulged.

Another circumstance which experience has made manifest has given security to the public on this point. It appears that the agents who are for many hours labouring at the machine in the transmission of despatches, word by word, rarely are able to give that kind of attention to the sense and purport of the whole which would be necessary to the clear understanding of it. Their attention is engrossed exclusively in the manipulation necessary to transmit letter after letter, and they have neither time n[illegible] attention to spare for the subject of the whole despatch. The ex[illegible]

is very analogous to that of compositors in a printing-office, who, as is well known, go through their work mechanically, without giving the least attention to the subject.

260. A sort of verbal ciphers, or abbreviations, are much in use, however, by mercantile houses. This is practised more for the sake of economy than secrecy, although the latter purpose is also attained. The firm and its correspondents have a key in which are tabulated a number of single words, each of which expresses a phrase or sentence, such as is of frequent occurrence in such communications. The following example of such a commercial despatch is given by Mr. Jones. The despatch to be sent consisted of 68 words, as follows:—

"*Flour Market for common and fair brands of western is lower, with moderate demand for home trade and export. Sales,* 8000 *bbls. Genesee at* 5 *dols.* 12. *Wheat, prime in fair demand, market firm, common description dull, with a downward tendency, sales,* 4000 *bushels at* 1 *dol.* 10. *Corn, foreign news unsettled the market; no sales of importance made. The only sale made was* 2500 *bushels at* 67 *c.*"

This despatch, when converted into the verbal cipher, was expressed in nine words, as follows:—

"Bad came aft keen dark ache lain fault adapt."

261. Complicated systems of cipher were invented for the transmission of parliamentary and law reports, and those of public meetings. When the tolls, however, were reduced by competition, this system was abandoned, and the reports were sent in full, or with such abbreviations only as are obvious.

262. The large quantity of telegraphic news which is published daily in the New York journals is explained by the fact, that seven of the principal journals of that city formed an association to telegraph in common, sharing the expense. Each journal was, however, at liberty to order for itself any extra intelligence, giving the others, or any of them, the option of sharing it.

263. Mr. Jones relates that one of the earliest telegraph feats, after the extension of the telegraph lines west to Cincinnati, was brought about by the agency of the "New York Herald," and before any regular association of the press was formed in New York.

"It became known that Mr. Clay would deliver a speech in Lexington (Ky.), on the Mexican war, which was then exciting much public attention. Mr. Bennett, editor and proprietor of the 'Herald,' desired us to have Mr. Clay's speech reported for the paper. We at once proceeded," says Mr. Jones, "to make arrangements to carry it into effect. We had a regular and efficient reporter already employed in Cincinnati, a Mr. G. Bennett; we also had a Mr. Thompson in Philadelphia in co-operation with us

for some papers there, and which agreed, if the speech was first received, to share the expense with the 'Herald.' The 'Tribune' in New York, and the 'North American' in Philadelphia, agreed to start for a report of the speech, in opposition. From Lexington to Cincinnati was eighty miles, over which an express had to be run. Horses were placed at every ten miles by the Cincinnati agent. An expert rider was engaged, and a short-hand reporter or two stationed in Lexington. When they had prepared his speech it was then dark. The express-man, on receiving it, proceeded with it for Cincinnati. The night was dark and rainy, yet he accomplished the trip in eight hours, over a rough, hilly, country road. The whole speech was received at the 'Herald' office at an early hour the next morning, although the wires were interrupted for a short time in the night, near Pittsburg, in consequence of the limb of a tree having fallen across them. An enterprising operator in the Pittsburg office, finding communication suspended, procured a horse, and rode along the line amidst the darkness and rain, found the place, and the cause of the break, which he repaired; then returned to the office, and finished sending the speech."

The Philadelphia "North American," upon whom the "Tribune" chiefly depended, failed to get its report, and the latter purchased a copy from the "Herald."

The expense of securing the speech by express and telegraph, amounted to about 100*l.*

The telegraphs have derived a very large share of their revenue from the press. The whole expense, for telegraph reports of all kinds, have some years cost the New York Associated Press (six in number) probably about 1000*l.* each, or a total of 6000*l.* per annum. The average for the past five years probably has not been less than about 5000*l.* to 6000*l.* per annum. During long sessions of Congress it exceeded this amount.

Sometimes a single paper availed itself of the privilege of ordering long and expensive reports of meetings, speeches, conventions, &c., in which its associates participated or declined as best suited their estimate of the value of the news. In case the other papers refused to receive it, the whole expense was borne by it. The "Herald" is the only one of its associates which publishes a Sunday paper—hence it takes all the telegraph news which is received on Saturday afternoon and night, and pays the whole expense of the tolls.*

264. The electric telegraph, an offspring of science, has rendered to its parent great and important services.

From the moment that it was discovered that the pulsations of

* Jones, p. 138.

the electric current could, by means of the conducting wires, be transmitted to any distances, its use in the important problem of the determination of longitudes, became conspicuously apparent. By reference to our Tract on Latitudes and Longitudes, it will be seen that the difference of the longitudes of two places upon the earth's surface is nothing more nor less than the difference of the hour of the day or night, as shown by two well-regulated clocks at the two places. Thus, if while it is 3 o'clock at one place, it is 4 o'clock at the other, the latter is one hour of longitude east, and the former one hour west of the other; or if it be preferred to express the longitude in degrees, the one place is 15° east or west of the other.

Now since the machinery of the electric telegraph supplies the means of making all the time-pieces of whatever kind, or where-ever placed, which are brought into connection with the same system of wires, move in exact accordance, it is capable of making all the time-pieces in the United Kingdom move in exact accordance with the standard chronometer of Greenwich Observatory; or, to take a still larger view of the principle, it is capable of governing the movement of all the time-pieces of whatever sort, and wherever situated within the range of the vast net-work of telegraphic wires, which overspreads the European continent, so as to make them move in accordance with any standard time-piece, which may by common consent be adopted as the common regulator.

Now, if such an uniformity of chronometers were established, the longitudes of all places would be determined by ascertaining by observations on the sun, which are always easy and susceptible of great precision, the local time, that is to say the time which would be shown by a well-regulated clock on the present system. The difference of the two times, that shown by the common standard regulator and that shown by the local clock, would be the difference of longitude between the place in question and the place where the standard regulator would show local time.

265. In places at great distances asunder, and in different countries, such horological uniformity would, at first, for civil purposes be attended with some inconvenience, since the hour of noon would vary with the longitude. Thus, at a place 15° east of the standard station, the hour of noon would be one o'clock, and at a place 15° west it would be 11 o'clock. Such an inconvenience would, however, only be felt at the moment of the change of custom. It is obvious that it would be as easy and simple to mark the moment at which the sun passes the meridian by 11 or 1, as by 12.

Incidentally to such an horological uniformity would arise, however, the convenience that the hour of noon at all places would express their longitude with relation to the standard station.

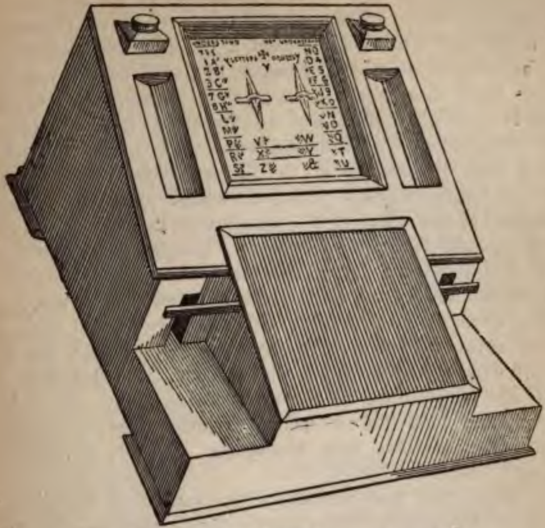


Fig. 91.—HENLEY'S MAGNETIC NEEDLE TELEGRAPH.

THE ELECTRIC TELEGRAPH.

CHAPTER XIII.

266. Signal time balls.—267. Electric connection of observatories of Greenwich, Brussels, and Paris.—268. Uses of electric telegraph in astronomical observations.—269. In regulating the observatory clocks.—270. In fixing with precision the time of an astronomical phenomenon.—271. Telegraphic lines of the United Kingdom.—272. Their extent in 1854.—273. Electric Telegraph Company.—274. Table of its lines, stations, &c.—275. Present tariff (1854).

266. By concert between the Astronomer Royal and the several Electric Telegraph Companies, the Greenwich local time is announced at certain hours of the day, at conspicuous places in different parts of the country, so that navigators who happen to be in any of our ports, may avail themselves of these means of regulating their chronometers. We have already explained the

signal given daily at one in the afternoon, by the fall of a large ball upon the dome of the Royal Observatory at Greenwich.* This being generally visible from a considerable extent of the river below London-bridge, masters of vessels observing it can regulate their time-pieces or note their errors. This system of signals is in progress of extension. By means of a galvanic clock at the Observatory, and the conducting wires which connect that building with the station of the Electric Telegraph Company at Lothbury, hourly signals giving accurately Greenwich time are transmitted to the offices of the company at Lothbury, and in the Strand opposite Hungerford-market. Similar signals are transmitted several times a day to Tunbridge, Deal, and Dover by the wires of the South-eastern Company. Signal balls are let fall over the dome of the Telegraph Office in the Strand and at an elevated station, Liverpool, at the same instant with the fall of the ball over the Greenwich Observatory. Besides this time-signals are transmitted on the wires twice a day, at 10 in the forenoon, and 1 in the afternoon, directly from Greenwich to various chief stations upon the system of lines of the Electric Telegraph Company.

267. From the first instant of the laying of the wires connecting the Greenwich Observatory with the stations of the South-eastern Railway Company and the Electric Telegraph Company, it was evident that one of the earliest and most useful applications of them would be the determination of the longitudes of several of the principal observatories in the British Isles and on the Continent. During the year 1853, the earliest opportunities were accordingly taken for determining the longitudes of Cambridge, Edinburgh, and Brussels, which was accomplished with complete success, as far as regards the galvanic communications and the observations of the signals at all the observatories.

The observatories of Greenwich, Brussels, and Paris are now placed in direct electric connection by the submarine cables between Dover, Calais, and Ostend, to the great advantage and advancement of astronomical science.

268. In the routine of the business of an observatory, the astronomical clock is an instrument in never ceasing use. A part of almost every astronomical observation consists in noting with the last degree of precision the moments of time at which certain phenomena take place; and so great is the degree of perfection to which the art of observation has been carried, that well-practised observers are able, by the combination of a quick and observant eye and ear, to *bisect a second*, and even to approach to a still

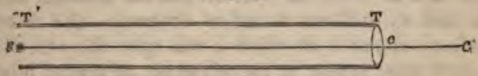
* See Tract on Latitudes and Longitudes.

more minute division of that small interval. In order to enable the reader fully to appreciate the benefit which the telegraph has rendered to astronomy, it will be necessary here briefly to explain the manner in which this kind of observation has hitherto been made.

To determine the moment at which the visual ray proceeding from a celestial object has some definite direction, two things are necessary—1st, to ascertain the direction of such a ray; and, 2ndly, to observe the time when it has such direction. The telescope, with its accessories, supplies the means of accomplishing the former, and the astronomical clock the latter.

If T T′, fig. 93, represent the tube of a telescope, T the extremity in which the object-glass is fixed, and T′ the end where the

Fig. 93.



images of distant objects to which the tube is directed are formed, the visual direction of any object will be that of the line *s′ c* drawn from the image of such object formed in the *field of view* of the telescope to the centre *c* of the object-glass, for if this line be continued, it will pass through the object *s*.

But since the field of view of the telescope is a circular space of definite extent, within which many objects in different directions may at the same time be visible, some expedient is necessary by which one or more fixed points in it may be permanently marked, or by which the entire field may be spaced out as a map is by the lines of latitude and longitude.

This is accomplished by a system of fibres or wires, so thin that even when magnified they will appear like hairs. These are extended in a frame fixed within the eye-piece of the telescope, so that they appear when seen through the eye-glass like fine lines drawn across the field of view.

The system consists commonly of five or seven equidistant wires, placed vertically at equal distances, and intersected at their middle points by a horizontal wire, as represented in fig. 94. When the instrument has been adjusted, the middle wire *m m′* will be in the plane of the meridian, and when an object is seen upon it, such object will be on the celestial meridian, and the wire itself may be regarded as a small arc of the meridian rendered visible.

The eye of the observer is occupied in watching the progress *of the object moving* over the wires in the field of view of the

telescope. His *ear* is occupied in noting, and his mind in counting the successive beats of the pendulum, which in all astronomical clocks is so constructed as to produce a sufficiently loud and distinct sound, marking the close of each successive second. The practised observer is enabled with considerable precision in this way to subdivide a second, and determine the moment of the occurrence of a phenomenon within a small fraction of that interval. A star, for example, is seen to the left of the wire *m m'* at *s*, fig. 94, at one beat of the pendulum, and to the right of it at *s'* with the next. The observer estimates with great precision the proportion in which the wire divides the distance between the points *s* and *s'*, and can therefore determine the fraction of a second after being at *s*, at which it was upon the wire *m m'*.

Fig. 94.

The fixed stars appear in the telescope, no matter how high its magnifying power be, as mere lucid points, having no sensible magnitude. By the diurnal motion of the firmament, the star passes successively over all the wires, a short interval being interposed between its passages. The observer, just before the star approaching the meridian enters the field of view, notes and writes down the *hours* and *minutes* indicated by the clock, and he proceeds to count the *seconds* by his ear. He observes the instant at which the star crosses each of the wires; and taking a mean of all these times, he obtains, with a great degree of precision, the instant at which the star passed the middle wire, which is the time of the transit.

By this expedient the result has the advantage of as many independent observations as there are parallel wires. The errors of observation being distributed, are proportionately diminished.

When the sun, moon, or a planet, or, in general, any object which has a sensible disk, is observed, the time of the transit is the instant at which the centre of the disk is upon the middle wire. This is obtained by observing the instants which the western and eastern edges of the disk touch each of the wires. The middle of these intervals are the moments at which the centre of the disk is upon the wires respectively. Taking a mean of the contact of the western edges, the contact of the western edge with the middle wire will be obtained; and, in like manner, a mean of the contacts of the eastern edge will give the contact of that edge with the middle wire, and a mean of these two will give the moment of the transit of the centre of the disk, or a mean of all the contacts of both edges will give the same result.

By day the wires are visible, as fine black lines intersecting and

spacing out the field of view. At night they are rendered visible by a lamp, by which the field of view is faintly illuminated.

These points being well understood, no difficulty will be found in understanding the manner in which the telegraph has conferred vastly increased facility and precision on such observations.

269. The first service which it has rendered is that of making all the clocks in the observatory absolutely synchronous. This has been already accomplished with regard to the solar clocks, that is, those which indicate mean or civil time. It may be, and no doubt will be, also accomplished, with still greater advantage to science, in the case of the astronomical clocks, that is, those which mark sidereal time. The several observers, occupied usually in different rooms, have each their own clock. Now, however perfect may have been the workmanship of these clocks, no two of them can be relied upon to go absolutely together for any length of time; therefore, one of the duties of the observer, and of the conditions of good observations, is to note the error of his clock—that is, its deviation from the standard chronometer of the observatory. These errors will be effaced by the expedient of putting all the clocks in the observatory in electrical connection, so that the pendulum of the standard chronometer shall regulate the pulsations of the current, and these pulsations again regulate the motion of all the other clocks.

We believe that the Astronomer Royal once contemplated this improvement, and most probably, when suitable opportunity shall be presented, he will carry it into practical effect.

270. The clocks being thus reduced to absolute accordance, the next service rendered by the telegraph to the astronomer consists in affording the means of ascertaining the instant of time at which any celestial object passes across the micrometer wires with greater facility and precision than were attainable by the use of the eye and ear in the method above described.

This improved method of observation, as it is now being prepared for the Greenwich Observatory, consists in a key-commutator placed under the hand of the observer, which governs a current transmitted to an electro-magnet, connected with a style placed over a cylinder coated with paper, upon which it leaves a puncture when it is driven down by the pulsation imparted to the current by the finger of the observer acting upon the key. The paper-covered cylinder is kept in uniform revolution at any desired rate by clock-work, and another style impelled by another current receiving its pulsations from the pendulum of the chronometer, is driven upon the paper with each beat of the pendulum, the interval between two successive marks made by this style representing one second of time.

Now let us suppose, for example, that by the motion imparted to the cylinder, an inch of the paper passes in each second under the style. The style moved by the clock will therefore leave a succession of marks upon the paper, at distances of an inch asunder. But the particular distance of these marks is unimportant, nor is it material that the cylinder should be moved with mathematical precision. If its motion for the short interval of a second be practically uniform, that will suffice.

When the object, a star for example, approaches the field of view, the observer, with his eye to the telescope, holds his finger over the key. He sees the star enter the field and approach the first wire. The moment it crosses the wire, he presses down the key, and the style gives a puncture to the paper on the cylinder. In the same manner, when the star crosses the second and succeeding wires, he again and again presses on the key, and thus leaves as many distinct marks on the paper as there are wires.

After the observation thus made has been concluded, the marks on the paper are examined, and their distances from the preceding and following marks made by the pendulum style are exactly measured, from which is inferred the fractional part of a second, between the moment at which the star crossed each of the wires, and the last beat of the pendulum.

In this way the time of the transit is ascertained to the hundredth part of a second.

The Astronomer Royal, noticing this method of observing in an address delivered before the Royal Astronomical Society, said, that "In ordinary transit observations, the observer listens to the beat of a clock while he views the heavenly bodies passing across the wires of the telescope; and he combines the two senses of hearing and sight (usually by noticing the place of the body at each beat of the clock) in such a manner as to be enabled to compute mentally the fraction of the second when the object passes each wire, and he then writes down the time in an observing-book. In these new methods he has no clock near him, or at least none to which he listens: he observes with his eye the appulse of the object to the wire, and at that instant he touches an index, or key, with his finger; and this touch makes, by means of a galvanic current, an impression upon some recording apparatus (perhaps at a great distance), by which the fact and the time of the observation are registered. He writes nothing, except perhaps the name of the object observed."

He further observed that it was expected that by this method the irregularities of observation would be greatly diminished, whether because the sympathy between the eye and the finger is more lively than between the eye and the ear, remains to

be determined. The Astronomer Royal proposes to use the "centrifugal or conical-pendulum clock" as an instrument superior in every way to those used in America; and "considering the problem of smooth and accurate motion as being now much nearer to its solution than it had formerly been, it might be a question whether, supposing a sidereal clock made on these principles to be mounted at the Royal Observatory, it should be used in communicating motion to a solar clock."

It is worthy of remark also, that punctures can be made upon the *same* revolving barrel by observers employed at two or more instruments erected in different rooms, by means of keys or commutators, which complete the circuit from the same battery to the same puncturing-point. This is at present done with two instruments at Greenwich. All necessity for comparing clocks is, of course, avoided.

Some difficulties occurred at first in imparting to the cylinder a sufficiently smooth and equable motion, the motion given by common clock-work being always one made by starts like that of the seconds' hand of a pendulum. It was to surmount this difficulty that the Astronomer Royal proposed the substitution of the centrifugal pendulum (resembling the governor of a steam engine) for the ordinary oscillating pendulum. In the report of the Astronomical Society, published in February, 1854, it was announced that "The various difficulties which occurred from time to time in the mechanism of the barrel or smooth-motion clock, used for giving motion to the cylinder on which will ultimately be recorded the transits made with the transit-circle and altazimuth, according to the American method of self-registration, have been overcome. It now carries the cylinders put in connection with it with perfect regularity, its rate having all desirable steadiness."

TELEGRAPHIC LINES OF THE UNITED KINGDOM.

271. The telegraphic lines established throughout these countries have been constructed altogether by private companies, chartered or incorporated by the legislature. The total extent of lines in actual operation in the beginning of 1854, was a little more than 8000 miles, upon which about 40000 miles of conducting wire were laid, which would give an average number of five conducting wires over the entire telegraphic net-work.

272. This vast machinery of electric communication has been erected by five or six different companies, but the chief part of it by two—the Electric Telegraph Company, and the English and Irish Magnetic Telegraph Company: the former possesses nearly

4500 miles of line, and more than 24000 miles of wire; and the latter 2200 miles of line, and 13000 miles of wire.

The capital of the former is nearly 800000*l.*, and that of the latter 300000*l.*

It is estimated that the total amount of capital invested in the telegraphic lines of the United Kingdom may amount to about a million and a half sterling.

THE ELECTRIC TELEGRAPH COMPANY.

273. This company was the earliest established, and was in operation for four years without any rival whatever, and for six years without any real competition. These circumstances will explain the large proportion in which the extent of this company's lines exceed all others.

The consequence of the exclusive possession of this important machinery of intercommunication combined with the want of all experience as to the extent to which the public in general might be disposed to avail itself of the advantages offered to them, was naturally and very excusably the establishment of a high tariff. The use of the telegraph was regarded, so far as related to private individuals, as a luxury rather than a necessary of social life, and so far as related to men of business, as an expedient likely to be resorted to only in cases of the most pressing urgency: conceding the justice of these views, a high tariff was not only defensible, but absolutely necessary to the protection of the interests of those who had invested their capital in the enterprise.

Time, experience, and habit, on the one hand, rendered the public familiar with the uses of the telegraph, and created a greater disposition to profit by it for the ordinary purposes of life; and on the other, supplied to the Company that experience of which its managers stood in need, and enabled them, without imprudent risk, to develop liberal and enlightened views in the commercial management of the enterprise. Gradual reductions were made in the tariff, which were further stimulated by the establishment of competitors; and a standard of tariff has been established which, as will presently appear, can leave no reasonable ground of complaint as compared with those of other countries. Whether a still further reduction and a nearer approach to the principle of the uniform postage system would not benefit the companies as well as the public is a question that time and experience alone can solve.

274. The following table, for which we are indebted to the Board of Directors of this company, shows the extent of its lines.

NAME OF RAILWAY.	No. of Miles of Wires.	No. of Wires.	No. of Double-needle Instruments.	No. of Single-needle Instruments.	No. of Printing Instruments.	No. of Bells.	No. of Magnets.
BANGOR AND CAERNARVON	26¼	3	2	4		4	
BIRMINGHAM, SHREWSBURY, AND STOUR VALLEY RAILWAYS.							
Birmingham, Wolverhampton, and Shrewsbury	138½	4	12			1	
Birkenhead, Lancashire, and Cheshire Junction	87½	2	3				
Birkenhead Tunnel				2		2	
Sutton Tunnel				2		2	
CHESTER AND HOLYHEAD	366¼	4	15				
EASTERN COUNTIES.							
London to Colchester	410	8	16				
Between Braintree and Maldon	36	3	3			3	3
London to Ely	650¼	9	36			26	23
Ely to Norwich			15	4		9	4
Fakenham to Norwich			11	6		10	
Norwich to Yarmouth } Lowestoft }			13	29		13	
Chesterford to Bury			7				1
Chesterford to Newmarket			6				
Ely to Peterborough	148¾	5	7			6	6
March to Wisbeach	27	3	2			2	2
Cambridge to St. Ives	44¼	3	6			6	6
Broxbourne to Hertford	21	3	2			2	2
Waterlane to Enfield	6	2	2			2	
Shoreditch to Chatham				18		2	
Eccles to Attleborough	3¾	1		2		2	
Audley End to Littlebury	4	2	2			2	
Shoreditch to Brick Lane	1	2	2			2	
Stratford to Woolwich	15	3	5			5	
Stratford to Clapton	0½	1				2	2
West Junction to Stratford Bridge	2¼	3	5			7	
Coal-siding to Angel Lane	0¼	1				2	
Forest Gate to Angel Lane	1	1				2	
Chobham Farm Line	1	1		6			
EASTERN UNION.							
Colchester to Ipswich	86¼	9	6			6	5
Ipswich to Managers' office	1	2	2				
EXETER AND CREDITON	83½	2	4				
FURNESS LINE.							
Lindal to Dalton	2½	2	2				
Whitehaven Tunnel	0¾	1		2		2	
GREAT NORTHERN.							
London to York	762	4	19		2		
London to York *via* Boston	421	2	8				
Peterborough to Grimsby	156½	2	7				
Boston to Retford	102	2	4				

NAME OF RAILWAY.	No. of Miles of Wires.	No. of Wires.	No. of Double-needle Instruments.	No. of Single-needle Instruments.	No. of Printing Instruments.	No. of Bells.	No. of Magnets.
Lincoln to Gainsborough	33½	2	2				
Grimsby to Docks	1	4	2				
Knottingley to Leeds	16	2	5				
Bawtry to Rossington	7	2	2			2	
GREAT WESTERN RAILWAY.							
London to Bristol	827¾	7	22		2		
London to Birmingham	257½	2	20				
London to Maidenhead	67½	3	9	9		9	
Slough to Windsor	12	4	1				
Reading to Basingstoke	31	2	2				
Oxford to Banbury	23	1				5	
Swindon to Gloucester *via* Cirencester	90	2	8				
Tetbury to Brimscombe	8¼	1		2		2	
Box to Corsham	3½	1		2		2	
Bath to Bristol	23	2	4				
Bristol and Exeter Railway . . .	531	6	13				
Yatton to Clevedon	8	2	2				
Tiverton Junction to Tiverton . .	20	4	2				
Taunton to Yeovil	50	2	6				
LANCASHIRE AND YORKSHIRE RAILWAY.							
Manchester to Normanton	355¼	7	31			8	
Summit Tunnel	3½	2	2			2	
North Dean to Bradford	20	2	5				
Wakefield to Normanton	16	4	Included in G.N.R.				
Waterloo to Southport	39¾	3	3			3	
Castleford to Methby	1½	2	Included in G.N.R.				
LANCASTER AND PRESTON, AND LANCASTER AND CARLISLE RAILWAY.							
Lancaster to Preston	42	2	2				
Lancaster to Carlisle	138	2	5				
Oxenholm to Kendal	8	4	2				
LONDON, BRIGHTON, AND SOUTH COAST RAILWAY.							
London to Brighton	202	4	17				
Brighton to Newhaven	29½	2	4				
London to Epsom	36	2	3				
London to Croydon	21	2	8				
Croydon to Epsom	7½	1		2			
Littlehampton to Ford	3½	2	2			2	
Bricklayers Arms to Deptford . . .	5½	2	2				
Bricklayers Arms Junction to Forest Hill	5	2	5				
Balcombe Tunnel	0¾	1		2		2	
Clayton Tunnel	1¼	1		2		2	
Crystal Palace Extension	15	10	6			2	
LONDON AND NORTH-WESTERN RAILWAY.							
LONDON AND BLACKWALL	20	4	4			2	
London to Colwich	1012	8	3		2		

NAME OF RAILWAY.	No. of Miles of Wires.	No. of Wires.	No. of Double-needle Instruments.	No. of Single-needle Instruments.	No. of Printing Instruments.	No. of Bells.	No. of Magnets.
Macclesfield to Liverpool	392	8	7		4		
London to Rugby	$744\frac{3}{4}$	9	15		3		
Bletchley to Blisworth	65	4	8			2	2
Euston to Camden	2	2	2			2	2
Primrose Hill Tunnel	$4\frac{1}{2}$	6	4			4	4
Watford Tunnel	3	3	2			2	2
Bletchley to Windsor	30	4	4			2	
Winslow to Banbury	$47\frac{1}{2}$	2	4			4	
Winslow to Oxford	48	2	5			2	
Winslow to Junction	4	2					
Buckingham to Goodshed	$0\frac{1}{2}$	2		2		2	
Blisworth to Peterborough	$141\frac{3}{4}$	3	10			7	7
Kilsby Tunnel	$5\frac{1}{4}$	3	2			2	2
Rugby to Market Harborough	$35\frac{1}{2}$	2	5				
Rugby to Leamington	30	2	1				
Rugby to Birmingham	$208\frac{1}{4}$	7	7				
Rugby to Tamworth	$160\frac{1}{2}$	6	2				
Tamworth to Colwich	68	4	2				
Birmingham to Manchester	595	7	17		1		
Crewe to Warrington	97	4	3				
Warrington to Newton Junction	$28\frac{1}{2}$	6	2				
Newton Junction to Liverpool	$162\frac{1}{4}$	11	6		3		
Newton Junction to Preston	97	4	4				
Newton Junction to Manchester	$150\frac{3}{4}$	9	3		1		
Macclesfield to Stockport	$29\frac{1}{2}$	2	3				
Stockport to Manchester	12	2	1				
Stockport to Guidebridge	10	2	Included above.				
Guidebridge to Eaton Lodge	$217\frac{1}{2}$	6	6				
Mirfield Junction to Leeds	40	4	4				
Saddleworth to Morsden	15	3	4			4	4
Huddersfield Tunnel	$1\frac{1}{2}$	3	3			3	3
Morley Tunnel	6	3	2			2	2
Manchester to Hardwick	$4\frac{1}{2}$	6	Included above.				
Warrington to Preston Brook Junction	19	4	Included above.				
Edge Hill to Lime-street	$2\frac{1}{2}$	2		2		2	
Edge Hill to Byron-street	2.	2		2		2	2
Waterloo to Wapping	$10\frac{1}{2}$	3	4			4	4
Curzon-street to Bescot	19	2	2				
LONDON AND SOUTH-WESTERN RAILWAY.							
Waterloo to Portsmouth	378	4	12				
Waterloo to Southampton	$78\frac{3}{4}$	1			2		
Bishopstoke to Southampton	33	6	4				
Fareham to Gosport	19	4	2				
Waterloo to Nine Elms	4	2	3				
Southampton to Dorchester	$184\frac{1}{2}$	3	8			8	
Poole Junction to Poole	$7\frac{1}{2}$	5	2			3	
Southampton to Brockenhurst	$30\frac{1}{2}$	2	1				

NAME OF RAILWAY.	No. of Miles of Wires.	No. of Wires.	No. of Double-needle Instruments.	No. of Single-needle Instruments.	No. of Printing Instruments.	No. of Bells.	No. of M…
Brockenhurst to Osborne . . .	64	2	4				
MANCHESTER, SHEFFIELD, AND LINCOLNSHIRE RAILWAY.							
Manchester to Sheffield . . .	165	4	10				
Denting to Glossop	4	4	1				
Sheffield to New Holland . . .	131⅓	2	10				
Ulceby to Great Grimsby . . .	19⅛	2	2				
Lincoln to Barnetby	59	2	6				
Woodhead to Dunford	6	2	2				
MARYPORT AND CARLISLE RAILWAY.							
Carlisle to Maryport . . .	56	2	9			5	
MIDLAND RAILWAY.							
Derby to Rugby	246½	5	10			2	
Derby to Peterborough	363¾	5	9			6	
Peterborough to Leicester . . .	159	3					
Melton Mowbray to Stamford . .	50½	2	2			2	
Derby to Lincoln	146¼	3	4			4	
Derby to Sawley	6¾	1				1	1
Derby to Normanton	442¾	7	15	14		21	1
Normanton to Leeds	75¼	7	7			3	
Leeds to Bradford	41¼	3	5			4	
Leeds to Skipton	78¾	3	7			6	
Apperley to Shipley Cabin . .	6½	2	2				
Skipton to Lancaster	78	2	1				
Hunslet to Hunslet Junction . .	0½	1				2	
Hunslet Junction to Waterlane . .	0¾	1		2		2	
Sheffield to Masbro'	15	3	2			2	
Derby to Willington	13	2				1	1
Derby to Birmingham	206¼	5	10			5	
Birmingham to Gloucester . . .	371	7	14			6	
Lickey to Bromsgrove		2	2				
Gloucester to Bristol	150	4	8				
MONMOUTHSHIRE RAILWAY AND CANAL.							
Newport to Blaina	39	2	7				
Newport to Pontypool	17	2	3				
Risca to Nine Mile Point . . .	2¾	1		2		2	
Aberbeeg to Ebbw Vale	5¼	1		2		2	
NORTH LONDON RAILWAY.							
Camden to Stepney	70	10					
Bow to Poplar	3	2	3				
NORTH STAFFORDSHIRE RAILWAY.							
Colwich to Macclesfield . . .	308	8	Included above.				
Colwich to Stone	46	4	3				
Norton Bridge to Stone . . .	11¼	3	2			2	
Stone to Stoke	49	7	3			1	
Stoke to Loco Works	1	2	2				
Stoke to Burton	88½	3	4			1	

NAME OF RAILWAY.	No. of Miles of Wires.	No. of Wires.	No. of Double-needle Instruments.	No. of Single-needle Instruments.	No. of Printing Instruments.	No. of Bells.	No. of Magnets.
Stoke to Newcastle-under-Lyne . .	3	2	2			2	
Stoke to Horecastle	50	8	4			2	
Stoke to Horecastle Tunnel . . .	1	2	2				
Stoke to Crewe	71¼	5	1			1	
Stoke to North Rode	27	3	Included above.				
North Rode to Macclesfield . .	23¾	5	3			1	
North Rode to Uttoxeter . . .	54⅛	2	4			3	
Rocester to Ashbourne	14	2	2			2	
OXFORD, WORCESTER, & WOLVERHAMPTON	115	2	13			2	
Worcester to Dudley	110	4	14				
Dudley to Wolverhampton . .	24	4	3				
SHREWSBURY AND BIRMINGHAM RAILWAY.							
Shrewsbury to Wolverhampton . .	118	4	9			1	
SHROPSHIRE UNION RAILWAY.							
Shrewsbury to Stafford	58½	2	3				
SHREWSBURY AND CHESTER RAILWAY.							
Chester to Shrewsbury	169	4	7			3	
Wheatsheaf Branch	4	4	1			1	
Oswestry Branch	9	4	1				
SHREWSBURY AND HEREFORD RAILWAY.							
Shrewsbury to Hereford	101	2	13			6	
Ludlow Race-course	1	4	1				
Ludlow Tunnel	1½	2					
Dinmore Tunnel	0¾	4	2			2	
NEWPORT, ABERGAVENNY, AND HEREFORD RAILWAY.							
Hereford Junction to Hereford Station	82	2	3				
HEREFORD, ROSS, AND GLOUCESTER RAILWAY.							
Grange Court to Hopebrook . . .	10	2	2				
SOUTH DEVON RAILWAY.							
Exeter to Plymouth	371	7	17			14	
Newton to Totness	17½	2	1				
Newton to Torquay	20	4	3				
Totness to Kingsbridge	9	1		3		3	
Plymouth to Kingsbridge . . .	15	1		3		3	
WEST CORNWALL RAILWAY.							
Penzance to Truro	50	2	7				
SOUTH-EASTERN RAILWAY.							
London to Strood	124	4	26			23	
London to Greenwich	7½	2	4			4	
London to Observatory	7½	2	For time signals.				
London to Tunbridge	164	4	9			9	
Tunbridge to Paddock Wood . .	25	5	2			2	
Paddock Wood to Maidstone . .	30	3	4			4	
Paddock Wood to Dover . . .	168	4	2	13		15	

NAME OF RAILWAY.	No. of Miles of Wires.	No. of Wires.	No. of Double-needle Instruments.	No. of Single-needle Instruments.	No. of Printing Instruments.	No. of Bells.	No. of Magneto
Folkstone to Harbour	6	6	3			3	
Ashford to Margate	102	3	8			8	
Minster to Deal	27	3	3			3	
Ashford to Hastings	54	2	6			6	
Tunbridge to Robert's Bridge	84		10			8	
Robert's Bridge to Hastings	24	2	3			3	
Brighton Junction to Hastings	6	2	3			3	
Bricklayers' Arms to Junction	4	4	1			1	
Redhill to Shalford	76	4	4			2	
Shalford to Reading	54	2	7				
Merstham Tunnel to Redhill	7	2		4		4	
Redhill to Signal Pole	$0\frac{1}{2}$	1				2	
SOUTH STAFFORDSHIRE RAILWAY.							
Bescott to Walsall	$7\frac{1}{2}$	5	3			2	2
Bescott to Great Bridge	6	2	2				
Great Bridge to Dudley	6	3	2	2		3	1
Walsall to Brownhills	$10\frac{1}{2}$	2	2				
SOUTH WALES RAILWAY.							
Gloucester to Haverfordwest	647	4	35				
Landore to Llamsamlit	7	2		6		6	
Tunnel west of Landore	2	1		2		2	
S.N. wire from S.W. to Taff Vale Railway	$0\frac{1}{2}$	1		2		2	
Loop to Swansea	14	8	2				
Cardiff Docks	5	4	1				
Gloucester to Grange Court	$15\frac{1}{2}$	2	1				
TAFF VALE RAILWAY.							
Cardiff Docks to Merthyr	49	2	5				
Aberdare to Aberdare Junction	$14\frac{1}{2}$	2	2				
VALE OF NEATH RAILWAY.							
Neath to Merthyr	46	2	5				
Hirwain to Aberdare Junction	1	1	2			2	
Merthyr to end of Tunnel	2	1		2		2	
WHITEHAVEN JUNCTION.							
Maryport to Whitehaven	24	2	4			4	
YORK, NEWCASTLE, AND BERWICK RAILWAY.							
York to Newcastle	$872\frac{1}{2}$	10	18	13	1	19	1
Darlington to Newcastle	$42\frac{3}{4}$	1				22	10
Darlington to Station on Stockton Line	$1\frac{3}{4}$	1		2			
Dalton to Richmond	$19\frac{1}{2}$	2	2			1	
Dalton to Darlington	$5\frac{1}{4}$	1					
Belmont to Durham	12	6	4				
Belmont to Fence Houses	$3\frac{1}{2}$	1				4	1
Brockley Whins to South Shields	24	8	2			3	
Newcastle to Brockley Whins	$47\frac{1}{2}$	5	Included below.				
Brockley Whins to Sunderland	35	7	3	2		3	
Newcastle to Berwick	399	6	8			7	

NAME OF RAILWAY.	No. of Miles of Wires.	No. of Wires.	No. of Double-needle Instruments.	No. of Single-needle Instruments.	No. of Printing Instruments.	No. of Bells.	No. of Magnets.
Newcastle to Benton	4	1					
Newcastle to Tynemouth	18	2	4				
Belton to Alnwick	12	4	2			1	
Fatfield to Washington	4	2		1		1	
Washington to Shields Drops	8	2		1		1	
Shields Drops to Sunderland Dock	16	2		1		1	
Sunderland Dock to Sunderland Statn.	8	2	Included above.				
YORK AND NORTH MIDLAND RAILWAY.							
Harrowgate to Church Fenton	48¾	3	2			2	
Hull to Milford Junction	77½	5	9			7	
Bridlington to Hull	30¾	3	5			5	
Scarborough to York	42¾	3	8			7	
Burton Salmon to Castleford	36	9	2			2	
Castleford to Normanton	33¾	9	2			1	
Milford Juncton to Burton Salmon	4	2					
Milford Junction to York	30	2	2				
York to Burton Salmon	217¾	13	10				8
EDINBURGH, PERTH, AND DUNDEE.							
Edinburgh to Tay Port	159	3	11			11	
Ladybank Junction to Perth	36	2					
Edinburgh to Scotland-street	1	2					
EDINBURGH AND GLASGOW RAILWAY.							
Edinburgh to Glasgow	332½	7	9		3	7	
Edinburgh to Greenhill	60	2	1				
Cowlairs to Hut Tunnel end	2½	2	2			2	
Haymarket to Edinburgh Tunnel end	3¾	2					
Edinburgh to Leith-street work	4	4	2				
DUNDEE AND ARBROATH RAILWAY.							
Dundee to Broughty	9	2	1				
Tay Port Submarine cable	4	4					
NORTH BRITISH RAILWAY.							
Berwick to Edinburgh	346½	6	10			10	
Portobello to Hut	6	2	2			2	
Tunnel	120 yds						
SCOTTISH CENTRAL RAILWAY.							
Greenhill to Perth	180	4	9			7	
METROPOLITAN STATIONS	500	52	71		5		

275. According to the tariff, as last arranged by the Electric Telegraph Company, all messages consisting of not more than 20 words are transmitted to distances not exceeding 50 miles for 1*s.*, to distances not exceeding 100 miles for 2*s.* 6*d.*, and to all

greater distances for 5*s*. For each additional ten words, or fraction of ten words proportionate charges are made.

In certain exceptional cases the shilling charge is extended to much greater distances than 50 miles, and the half-crown charge to much greater distances than 100 miles. These exceptions include towns of the highest commercial and manufacturing importance, with which a large telegraphic business must always be transacted. Thus, between London and Birmingham (112 miles) the charge is only 1*s*., and between London and Liverpool (210 miles), London and Manchester (180 miles), London and Carlisle (309 miles), the charge is only 2*s*. 6*d*.

The charge for transmission is of course increased in proportion to the length of the message, but the daily experience of the telegraphic offices demonstrates that, with the exception of reports transmitted to the newspapers, the average length of the messages does not much exceed twenty words. I have obtained a return of the lengths of 74 messages transmitted, without any particular selection of subject, the total length of which, exclusive of the address, is 1151 words. The total length of the addresses is 540 words. This gives for the average length of the messages 15½ words, and of the addresses 7¼ words, the average length of the messages, including the addresses, being therefore a little under 23 words.

Besides the convenience offered to the public by the transmission of messages to the various stations throughout the country, this Company has established a system of metropolitan intercommunication by means of seventeen branch stations in connection with each other and with the principal station at Lothbury. These stations are dispersed through the metropolis at points which have been found to be the most active centres of intercourse. They include the eight railway stations, the London Docks, Mincing Lane, General Post-office, St. Dunstan's Church, West Strand, Great George Street Westminster, St. James's Palace, Knightsbridge, and the Marble Arch, Hyde-park. Of these the stations on the West Strand, and the Eastern Counties Railway, Shoreditch, are open day and night.

Messages of 20 words are transmitted between any two of these metropolitan stations for 1*s*.

In all cases the charge for the telegraphic message includes its delivery at the place of address, provided that such place be within a radius of half a mile round the station, 6*d*. being charged for each mile additional, and no charge is made for the addresses of the sender or receiver.

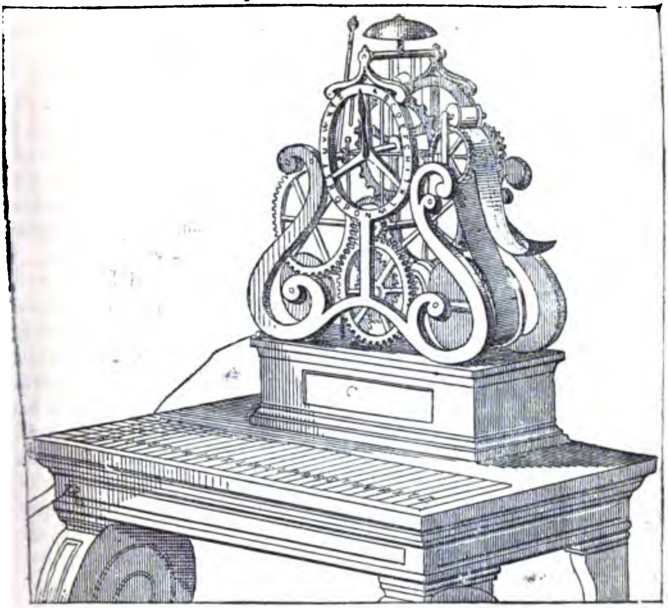


Fig. 92.—BRETT'S PRINTING TELEGRAPH.

THE ELECTRIC TELEGRAPH.

CHAPTER XIV.

Electric Telegraph Company's present tariff (continued).—276. Magnetic Telegraph Company.—277. Chartered Submarine Company.—278. The Submarine Telegraph Company. between France and England.—279. European and American Telegraph Company.—280. Origin of the submarine companies' enterprises.—281. Wonderful celerity of international correspondence.—282. Organisation of electric communications with the Continent.—283. Mediterranean Electric Telegraph Company. —284. General table showing the places on the continent of Europe, which are in electric connection with each other, and with England, and the cost of despatches sent between them severally and London.—285. Telegraphic lines in the United States.—286. Vast projects in progress or contemplation.

According to the half yearly balance sheet of the company it appears that in the six months ending December 31, 1853, tho

gross revenue amounted to 56919*l.*, and that the dividend was 7 per cent. per annum on the capital.

The receipts would represent an average daily business of about 6200 shilling messages.

This company possesses the English patent of many forms of telegraph, including those of Bain. It works, however, chiefly with the double needle telegraph, impelled by currents from the ordinary plate battery of zinc and copper, excited by acidulated water. The transmission of each despatch, consequently, occupies two conducting wires, and two batteries with their accessories.

On certain lines, as for example between London and Liverpool, the instrument of Bain is used. This is attended, as compared with the needle instrument, with two advantages; first, that it requires only one line wire; and secondly, that it writes its own despatch. With the needle instrument two copies of each despatch must be made, one to be delivered as addressed, and the other to be retained by the office. In using Bain's method, that which is written in telegraphic cipher by the instrument is retained by the office, so that the time of one clerk is saved.

In the organisation of its establishment, the Electric Telegraph Company have made an innovation on our national customs, which cannot be regarded as otherwise than happy and judicious, by rendering electro-telegraphy the means of enlarging the sphere of female industry in this country. In no part of the civilised world, —except perhaps the United States, where our customs have been retained,—are females excluded from so many employments suited to them, as in England. In France they are extensively employed as clerks in various branches of commercial business. As money-takers or ticket-sellers in railway offices, theatres, concert-rooms, and in short in all public exhibitions they are engaged, to the entire exclusion of the other sex. As box-keepers and box-openers in all the theatres, and in numberless other occupations in which no bodily labour is needed, they are preferred to men.

Now the working of telegraphic instruments, and the general business of telegraphic offices is precisely the kind of occupation for which they are best fitted, and we notice with great pleasure the independent and enlightened step taken by the Electric Telegraph Company in their employment, which it may be hoped will prove only the commencement of a general movement, having a tendency to improve the condition of that portion of the sex who are obliged to seek the means of living by their industry.

The battery department is not one of the least interesting objects presented in the Lothbury establishment. The cellars of the building are appropriated to this generator of electric currents.

They consist of two long narrow vaults, in which upwards of 300 batteries are arranged, consisting of various numbers of pairs of plates, six, twelve, and twenty-four, adapted to carry smaller and greater distances.

The entire amount of voltaic power employed by this company throughout the country consists of 96000 cells composed of 1,500000 square inches of copper, and an equal surface of zinc. These are kept in action by the consumption of six tons of acid annually.

In the half year ending 31st December, 1851, the paid up capital of the company was augmented, and the tariff for the transmission of messages was reduced in the large proportion of 50 per cent. upon its original rate. The extent of the line was increased 8 per cent., and that of the conducting wires nearly 35 per cent. The average number of wires upon the lines was augmented by this change from 4 to 5. The effect of this, and the gradual increase from month to month in the next half year was an increase of above 60 per cent. in the amount of business, and nearly 13 per cent. in the receipts, the dividends having been augmented from 4 to 6 per cent.

Among the more recent improvements in the transaction of telegraphic business which have been made by this company, the following may be mentioned.

"Franked message papers," pre-paid, are now issued, procurable at any stationer's. These, with the message filled in, can be dispatched to the office when and how the sender likes; and the company intend very quickly to sell electric stamps, like Queen's heads, which may be stuck on to any piece of paper, and frank its contents without any further trouble. Another very important arrangement for mercantile men is the sending of "remittance messages," by means of which money can be paid in at the central office in London, and, within a few minutes, paid out at Liverpool or Manchester, or by the same means sent up to town with the like dispatch from Liverpool, Manchester, Bristol, Birmingham, Leeds, Glasgow, Edinburgh, Newcastle-on-Tyne, Hull, York, Plymouth, and Exeter. There is a money-order office in the Lothbury establishment to manage this department, which will, no doubt, in all emergencies speedily supersede the government money-order office which works through the slower medium of the post-office.*

* Quarterly Review, No. CLXXXIX., p. 149.

The effect of the gradual reduction of the tariff upon the business, and the profits of the company, will be apparent from the following table:—

Half Year Ending	Miles in operation.	Increase per cent.	Miles of line wire.	Increase per cent.	Mean Number of Wires.	Number of Messages.	Increase per cent.	Total Receipts. £ s. d.	Increase per cent.	Average Receipts per Message. s. d.	Average Receipts per Mile of Wire. £	Dividends paid per cent. per annum.
June 30, 1850 .	1684	...	6730	...	4	29245	...	20436 10 0	...	13 11¾	5·04	4
Dec. 31, 1850 .	1786	6·06	7200	6·98	4	37389	27·84	23087 13 9	12·97	12 4	3·20	4
June 30, 1851 .	1965	10·02	7900	9·72	4	47259	26·39	25529 12 4	10·56	10 9½	3·23	6 and 2 per cent. bonus.
Dec. 31, 1851 .	2122	99	10650	34·81	5	53957	14·17	24336 8 10	-4·67	90 ¼	2·29	6
June 30, 1852 .	2502	17·91	12500	17·37	5	87150	61·52	27437 4 8	12·74	6 3½	2·19	6
Dec. 31, 1852 .	3709	48·24	19560	56·48	5⅕	127987	46·86	40087 18 2	46·11	6 3¼	2·05	6½
June 30, 1853 .	4008	8·06	20800	6·34	5⅗	138060	7·87	47265 16 3	17·90	6 10	2·27	6½
Dec. 31, 1853 .	4409	10·00	24340	17·02	5½	212440	53·87	56919 0 1	20·42	5 4½	2·34	7
June 30, 1854 .	4652	5·51	25233	3·67	5½	235867	11·03	62435 0 0	9·69	5 3½	2·47	......

THE MAGNETIC TELEGRAPH COMPANY.

276. This Company has constructed lines connecting the following principal places by means of the submarine cable, extended between Donaghadee and Port Patrick:—

London.	Portpatrick.	Kildare.
Birmingham.	Donaghadee.	Carlow.
Manchester.	Belfast.	Thurles.
Liverpool.	Armagh.	Tipperary.
Preston.	Drogheda.	Limerick.
Carlisle.	Navan.	Waterford.
Glasgow.	Dublin.	Mallow.
Greenock.	Athlone.	Killarney.
Edinburgh.	Ballinasloe.	Cork.
Stranraer.	Galway.	Queenstown.

This company has established an underground line of ten wires from London to Liverpool, by Manchester, and one of six wires from Liverpool to Portpatrick, and from thence to Belfast. The line from Belfast to Dublin, and from thence to Cork, with branches, is overground on poles. The underground system is again adopted from Cork to Queenstown.

Lines are in progress of construction along the Waterford and Limerick Railway, and six additional wires are being laid between Dublin and Belfast.

The instruments used are the needle-telegraph, and chiefly the double needle instruments, the current being produced not by galvanic batteries, but by magneto-electric machines, on the principle patented by Messrs. Henley and Forster (220) improved in various details by the Messrs. Bright, the secretary and engineer of the company.

The speech delivered by the Queen on opening the parliamentary session of 1854, was supplied verbatim to the Belfast journals at 2 h. 25 m., to those of Dublin at 2 h. 40 m., and to those of Cork at 3 h. 20 m. on the afternoon of its delivery.

The tariff is regulated upon principles similar to that of the Electric Telegraph Company.

Although this company was not incorporated until the middle of 1852, it has now (July, 1854) upwards of 2000 miles of telegraphic lines, and 13000 miles of wire in active operation, and from the rapid progress it has hitherto made, and its power to extend its capital of 300000*l.* to 600000*l.*, it is probable that ere long its scale of operation will be much further extended, to the great benefit of the public.

SUBMARINE COMPANIES.

277. The CHARTERED SUBMARINE TELEGRAPH COMPANY between Great Britain and the Continent has been formed with a nominal share capital of 150000*l.*, of which the half has been for the present reserved, the actual amount of the subscribed capital being only 75000*l.*

The operations of this company have hitherto (1854) been limited to the establishment of electric communication with Belgium, by means of the cable already described, connecting Dover with Ostend.

This company has recently coalesced with the Submarine Telegraph Company.

278. The SUBMARINE TELEGRAPH COMPANY between France and England has a nominal share capital of 100000*l.*, of which about 75000*l.* have been subscribed and expended, the shares representing the remainder being still unallotted. The operations of this company have been limited to the establishment of electric communication between France and England, by means of the submarine cable laid between Dover and Calais.

279. The EUROPEAN and AMERICAN ELECTRIC TELEGRAPH COMPANY has been established to form a link between the cables of the two submarine companies, and London, Manchester, and Liverpool, and intermediate places. This company has laid underground wires from Dover to London, and from London by Birmingham and Manchester to Liverpool. Of this line, the first section between Dover and London was opened for public correspondence on 1st November, 1852, and has since been in constant operation. Of the remainder, 190 miles were completed on 1st March, 1854, passing through Birmingham, Wolverhampton, Stafford, and Macclesfield, to Manchester. The remaining 30 miles to Liverpool has been since completed, and the entire line is now in operation. The total cost of this line, with its accessories, has been 100000*l.*

By an arrangement between this and the Submarine Company, all despatches between the offices of the latter from the Continent are transmitted upon the lines of the former, being delivered and received at the offices of the latter. In fact, so far as the public are concerned, the continental correspondence going or coming by France or Belgium is transmitted by these three companies, acting in common and as a single administration. Offices for correspondence between England and the Continent are established in London, Birmingham, Manchester, Liverpool, Gravesend, Chatham,

Canterbury, Deal, Dover, Calais, Paris, Brussels, and Antwerp; despatches, however, being forwarded to England from all continental stations.

The tariff for all single messages between London and the Continent is 8*s*., in addition to the Continental charge for transmission between the Continental station to or from which the message is transmitted, and Calais or Ostend. If the message is sent to or from any provincial town (except Dover), there is an additional charge for its transmission between London and such town.

280. The originators of the novel and bold project of submarine electric communication are stated to be the Messrs. Jacob and J. W. Brett, brothers, of Hanover-square, London. Their first propositions were addressed to the English government, and were directed to the deposition of a submarine cable between Holyhead and Dublin, which they offered to undertake if the government would make them a grant of 20000*l*., for which, of course, the State would have for public purposes the free use of the line. This offer was declined.

The next propositions, addressed to the French and Belgian governments, were attended with more success. An exclusive privilege was granted by both governments, to which the English government acceded for the use of such submarine conductors as the parties should succeed in depositing, and in consequence of this, the companies were formed, by which the project has since been realised, and the cables already described between the English coast near Dover and the coasts of France and Belgium, near Calais and Ostend, were laid, by which London, Paris, and Brussels have been brought into and now are in instantaneous electric communication; and through these capitals the whole Continent, wherever telegraphic wires have been established, has been put in connection with the United Kingdom.

281. The actual celerity with which correspondence can be transmitted between London and parts of Europe more or less remote, may be judged from the fact that the Queen's speech, delivered at the opening of the parliamentary session of 1854, was delivered verbatim and circulated in Paris and in Berlin before her Majesty had left the House of Lords.

Messages have been sent from the office in Cornhill to Hamburg, Vienna, and, on certain occasions, to Lemberg, in Gallicia, being a distance of 1800 miles, their reception being acknowledged by an instantaneous reply.

282. It is satisfactory to be able to state that measures are being taken by many of the most important continental states to extend the benefits of telegraphic communication by multiplying the

stations, by increasing the number of conducting wires, and by lowering the tariff.

The electric communications with the continent may now be considered as secure from all chance of interruption. Accidents from the dragging of anchors may occur, by which any one of the submarine cables may be disabled for a time, but in that case the communication with the continent will be maintained by either or both of the others, such a coincidence as the simultaneous disabling of all the three not being within the bounds of moral possibility.

MEDITERRANEAN ELECTRIC TELEGRAPH COMPANY.

283. Another company has been formed by the spirit and enterprise of the Messrs. Brett, under the auspices of the governments of France and Piedmont, for connecting the coasts of Europe and Africa by electric wires, in the manner already explained (84). This company is formed with a share capital of 300000*l*. An exclusive privilege for fifty years has been granted to it by the two governments, and a guarantee of interest of four per cent. on 180000*l*. is given by the French, and 5 per cent. on 120000*l*. by the Sardinian Government.

This enterprise is now (1854) in rapid progress of realisation, several hundred men being occupied in constructing the lines across the islands of Sardinia and Corsica. It is expected that the lines to the coast of Africa will be completed and in operation soon after these pages will be in the hands of our readers.

While we write these lines (June, 1854) we learn that the cable has been laid between Spezzia and Corsica, and between Corsica and Sardinia, and is already in successful operation.

The condition and form of the bottom between coast and coast has been ascertained by soundings, and is found to present no obstacles, being free from any considerable inequalities of depth. The conducting wires within this cable have received a special form, the advantage of which is, that in case of the cable being bent by any accidental inequalities of the bottom, or accidents in the process of its deposition, the wires will not be strained, but will easily yield as a spiral spring would. In the cables already laid, it has been found that some of the wires have been more or less injured from this cause, so as to render their performance unsatisfactory.

The weight of this cable is at the rate of 8 tons per mile. It contains six conducting wires, each of which is covered with a coating of gutta percha, and the whole is surrounded with hemp, properly tarred, so as to form a compact rope, which is finally

enclosed like those already described in a compound heliacal armour of twelve galvanised iron wires.

Until the cable and wires destined ultimately to connect Alexandria with Sardinia can be completed, it is intended to establish a special line of steamers between Malta and Sardinia, so as to be enabled to transmit intelligence instantaneously from the centre of the Mediterranean to London, Paris, and all parts of Europe. Two mercantile houses, Messrs. Rubattino and Co., of Genoa, and Messrs. Antonio Galea and Co., of Malta, have undertaken conjointly to place two steamers to run between Malta and Sardinia, to take the despatches coming from the East, to be transmitted to Paris and London.

It is intended, however, meanwhile, to connect Malta by a cable with the nearest point of the African coast, and by this, and an underground line of wires to Bona, to establish an electric communication with Sardinia, and thence with London.

284. In the following table, collected from the most recent reports, are shown the telegraphic stations established in various countries of Europe in July, 1854. Annexed to each place is the charge at which a single message is transmitted between it and London. Of this charge 8s. is the part applicable to the transit between London and Calais or Ostend, the remainder being the cost of transmission between one or other of these places, and the continental station. A single message cannot exceed 20 words if transmitted by Calais, or 25 words if transmitted by Ostend. The charge is increased in a two-fold ratio for messages which exceed this number of words, but which do not exceed 50, and in a three-fold proportion for such as exceed 50, but do not exceed 100. In general, messages exceeding 100 words are not transmitted.

In some cases a message may be transmitted by different routes at the option of the person sending it. Thus, for example, a message to Vicenza may be sent *viâ* Baden, *viâ* Bavaria, *viâ* Switzerland, *viâ* Sardinia, or *viâ* Belgium. The cost of transmission in such cases varies with the route chosen. In all such cases the charge given in the Table is the lowest of those at which it can be sent.

The tariff by way of the Hague is not included in this Table.

FRENCH STATIONS, *viz.*	s.	d.	FRENCH STATIONS, *viz.*	s.	d.
To ABBEVILLE	10	6	To Lorient...	15	0
,, Agen	17	0	,, Lyons	16	0
,, Amiens	11	0	,, MACON...	15	0
,, Angers	14	0	,, Mans (le)	13	0
,, Angoulême	15	6	,, Marseilles	18	6
,, Arras	10	6	,, Melun	12	6
,, Auch	17	6	,, Metz	13	6
,, Auxerre	13	6	,, Mont-de-Marsan ...	17	6
,, Avignon	17	6	,, Montpellier	18	0
,, BAR-LE-DUC	13	0	,, Montauban	17	0
,, Bayonne	18	0	,, Montbrison	15	0
,, Beauvais	11	6	,, Moulins	14	6
,, Behobie	18	6	,, Mulhouse	15	0
,, Besançon	15	0	,, NANTES	14	6
,, Bezières	18	0	,, Nancy	13	6
,, Blois	13	6	,, Narbonne	18	0
,, Bordeaux	16	6	,, Nevers...	14	0
,, Boulogne-sur-Mer ...	10	0	,, Nimes	17	6
,, Bourges	14	0	,, Niort	15	0
,, Brest	15	0	,, ORLEANS	13	0
,, CAEN	13	0	,, PARIS	12	0
,, Cahors...	16	6	,, Pau	18	0
,, Calais	8	0	,, Perigueux	16	0
,, Carcassone	18	0	,, Perpignan	18	6
,, Cette	18	0	,, Poictiers	14	6
,, Chalons-sur-Marne ...	12	6	,, Privas...	16	6
,, Chalons-sur-Saone ...	15	0	,, QUIMPER	15	0
,, Chartres (Eure et Loir)	12	6	,, RENNES	14	0
,, Chateauroux	14	0	,, Rochefort	15	6
,, Chaumont	13	6	,, Roubaix	10	6
,, Cherbourg	12	6	,, Rouen	11	6
,, Clermont Ferrand ...	15	6	,, SAINT QUENTIN ...	11	6
,, Colmar (Alsace) ...	14	6	,, St. Etienne	16	0
,, Creil	11	6	,, St. Lo	12	6
,, DIEPPE...	11	0	,, St. Omer	10	0
,, Dijon	14	6	,, Strasbourg	14	6
,, Douai	11	0	,, TARBES...	18	0
,, Draguignan	18	6	,, Tonnerre	13	6
,, Dunkirk	10	0	,, Toulon...	19	0
,, EVREUX	12	0	,, Toulouse	17	6
,, FOIX	18	6	,, Tours	14	0
,, GRENOBLE	16	6	,, Troyes...	13	0
,, HAVRE...	12	0	,, VALENCIENNES ...	11	0
,, LAON	12	0	,, Valence	16	6
,, La Rochelle	15	6	,, Vannes...	14	6
,, Lille	10	6	,, Versailles	12	0
,, Limoges	15	6	,, Vesoul...	14	6

TO	s. d.	TO	s. d.	TO	s. d.
ARAU	20 0	Brunswick	20 0	Ghent	10 0
Aarbourg	20 0	Brussels	12 0	Giessen	18 0
Adelsberg	22 0	Bühler	22 0	Glaris	22 0
Aeltre	10 0	CARLSRUHE	14 0	Glognitz	22 0
Agram	22 0	Casale	24 0	Gorlitz	22 0
Airolo	22 0	Cassel	18 0	Gospich	22 0
Aix-la-Chapelle	16 0	Charleroi	12 0	Gotha	18 0
Alexandria (Sar.)	24 0	Chaux de Fonds	22 0	Goritz	22 0
Alstätten	22 0	Chemnitz	20 0	Gratz	22 0
Altenbourg	20 0	Chiasso	24 0	HAARLEM	16 0
Altona	24 6	Cilly	22 0	Hagenau	22 0
Altorf	22 0	Coire	22 0	Hague	14 0
Amsterdam	16 0	Come	18 0	Halle	20 0
Andermatt	22 0	Courtrai	10 0	Ham	18 0
Ansbach	18 0	Coblentz	18 0	Hamburg	22 0
Antwerp	12 0	Cologne	16 0	Hanau	18 0
Arnheim	16 0	Copenhagen	24 6	Hanover	20 0
Appenweier	18 6	Cracow	24 0	Harburg	22 0
Aschaffenburg	16 0	DANTZIG	24 0	Hasselt	12 0
Asti	22 0	Darmstadt	15 0	Hattingen	14 0
Ath	12 0	Delemont	20 0	Heidelberg	14 0
Augsburg	18 0	Delft	16 0	Heilbronn	16 0
BADEN, Baden	14 0	Dessau	20 0	Herisau	22 0
Baden (Swiss)	20 0	Deutz	16 0	Hermanstadt	26 0
Bale	20 0	Dirschaw	24 0	Herzogenbuchsee	20 0
Bamburg	18 0	Dordrecht	14 0	Hof	20 0
Bautzen	22 0	Dresden	20 0	Hohenschwangau	18 0
Bellinzona	22 0	Dinglingen	14 0	Horgen	22 0
Bergamo	20 0	Duisbourg	18 0	INSPRUCK	18 0
Berlin	22 0	Dusseldorf	18 0	Ischl	24 0
Berne	20 0	EMPOLI	35 0	JURBISE	12 0
Berthoud	20 0	Eisenach	18 0	KARLSTADT	22 0
Beyreuth	18 0	Elberfeld	18 0	Kempten	18 0
Bielitz	26 0	Elbing	26 0	Kell	14 0
Bienne	20 0	Elsineur	24 6	Kissengen	18 0
Bodenbach	20 0	Erfurt	20 0	Klagenfurt	22 0
Bologna	26 0	Essek	28 0	Klausenberg	30 0
Borgoforto	24 0	FELDKIRK	18 0	Kohlfurt	24 0
Botzen (in Tyrol)	20 0	Flawyl	22 0	Konigsberg	26 0
Brain-le-Compte	12 0	Flensburg	24 6	Korsör	24 6
Breda	14 0	Fleurier	22 0	Kosel	24 0
Bregenz	18 0	Florence	36 6	Kothen	20 0
Bremen	20 0	Fossano	22 0	Kreutz	24 0
Brescia	20 0	Frankfort on M.	15 6	Kufstein	20 0
Breslau	22 0	Frankfort on O.	22 0	LAIBACH	22 0
Brigg	22 0	Frauenfeld	22 0	Landau	14 0
Brixen	20 0	Fredericia	24 6	Landen	12 0
Bromberg	26 0	Fribourg (Swiss)	22 0	Landshut	18 0
Bruchsal	14 0	Friburg (Baden)	14 0	Langenthal	20 0
Brugelette	12 0	Friedrichshafen	16 0	Lans-le-bourg	20 0
Bruges	10 0	GENEVA	22 0	Lausanne	22 0
Brugg	20 0	Genoa	24 0	Leghorn	34 6
Brunn	22 0	Germersheim	14 0	Leipzig	20 0

TO	s.	d.	TO	s.	d.	TO
Lemburg	26	0	Offenburg	14	0	Saint Imier
Lenzbourg	20	0	Olmutz	22	0	Saint Trond
Leyden	16	0	Olten	20	0	St. Jean de Mau-
Lichtensteig	22	0	Oos	14	0	rienne
Liege	12	0	Oppeln	24	0	Salzburg
Liegnitz	22	0	Orsowa	26	0	Samaden
Liestall	20	0	Oschersleben	20	0	Sarrebrück
Lindau	16	0	Ostend	8	0	Schiedam
Linz	20	0	Paderborn	20	0	Schaffhausen
Locarno	22	0	Padua	20	0	Schweinfurt
Locle (le)	22	0	Parma	24	0	Schwyz
Louvain	12	0	Passau	20	0	Semlin
Lubeck	22	0	Pays Bas Frr.	12	0	Sion
Lucca	34	6	Pepinster	14	0	Sienna
Lucerne	22	0	Pescia	35	0	Soleure
Ludwigschafen	16	0	Pesth-Bude	24	0	Sonceboz
Lugano	24	0	Peterwardin	24	0	Spires
Magdeburg	20	0	Pietra Santa	32	6	Splügen
Malines	12	0	Pirano	22	0	Stettin
Manage	12	0	Pisa	32	6	Stuttgard
Mannheim	14	0	Pistoja	37	0	Süssen
Mantua	20	0	Plaisance	26	0	Swinnemunde
Marburg	18	0	Plauen	20	0	Szegedin
Massa	26	0	Poggebonsi	37	0	Szolnock
Mestre	20	0	Pola	22	0	Tamines
Milan	20	0	Pontadera	33	0	Tarnow
Minden	20	0	Posen	24	0	Temeswar
Misocco	22	0	Potsdam	22	0	Termonde
Modena	24	0	Prague	20	0	Teufen
Mogadino	22	0	Prato	37	0	Thalwyl
Mons	12	0	Presburg	22	0	Thusis
Monza	20	0	Przmysl	26	0	Tirlemont
Morat	22	0	Quievrain	12	0	Tournay
Morgiers	22	0	Racconigi	22	0	Trento
Motiers	22	0	Ragaz	22	0	Treves
Mouscron	10	0	Rapperschwyl	22	0	Treviglio
Mulheim	14	0	Rastadt	14	0	Trevisa
Munich	18	0	Ratibor	24	0	Trieste
Munster	18	0	Ratisbon	18	0	Trogen
Murzzuschlag	22	0	Reggio	22	0	Troppau
Myslowitz	24	0	Rendsburg	24	6	Trubau
Namur	12	0	Rheineck	22	0	Turin
Neufchâtel	22	0	Richterschwyl	22	0	Udine
Neuhausel	24	0	Riesa	20	0	Ulm
Niederurnen	22	0	Rotterdam	14	0	Utrecht
Nieuw Diep	17	8	Rorschach	22	0	Uznach
Novare	24	0	Rosenheim	18	0	Venice
Novi	24	0	Roveredo	20	0	Verceil
Nuremburg	18	0	Rovigno	32	0	Verona
Nyburg	24	6	Rzeszow	26	0	Verviers
Nyon	22	0	Saint Gall	22	0	Vevey
Oderberg	24	0	Sainte Croix	22	0	Vicenza
Offenbach	16	0	Saint Ghislain	12	0	Vienna

TO	s. d.	TO	s. d.	TO	s. d.
Wadenschwhl ...	22 0	Winterthur ...	22 0	YVERDUN ...	22 0
Wattwyl ...	22 0	Wittenburg ...	22 0	ZOFFINGUE ...	20 0
Weimar ...	20 0	Worms ...	16 0	Zug	22 0
Werdau ...	20 0	Wurzburg ...	18 0	Zurich	22 0
Wesel ...	20 0	Wyl	22 0	Zwickau ...	20 0

*** *The above rates are exclusive of the usual charge for Porterage for Delivery of the Messages to any part of France. No charge to other places. N.B.—The Minimum length of a Message viâ Belgium is Twenty-five Words, any other route Twenty Words.*

The Public are informed that, in order to provide against mistakes in the transmission of MESSAGES by the SUBMARINE and EUROPEAN TELEGRAPH COMPANIES, every Message of consequence ought to be REPEATED, by being sent back from the Station at which it is to be received, to the Station from which it is originally sent.—Double the usual price for transmission will be charged for repeating the Message to or from any part of France, and Half the usual charge to or from any other part of Europe.—The Company will not be responsible for Mistakes in the transmission of unrepeated messages, from whatever cause they may arise.—Nor will they be responsible for Mistakes in the transmission of a repeated Message, nor for delay in the transmission or delivery, nor for non-transmission or non-delivery of any Message, whether repeated or unrepeated.—No Message that is unintelligible can be transmitted to the Continent in consequence of the regulations of the Foreign Governments.—These Companies reserve to themselves the right of refusing all those Despatches which in their opinion are unintelligible.—All persons sending more than one Message as a Single Despatch will be held liable to pay such further sum, in addition to the amount paid on transmission, as would have been charged by these Companies if each message had been sent separately.

TELEGRAPHIC LINES IN THE UNITED STATES.

285. Owing to the rapid progress and unrestricted freedom of enterprise in the United States, a great number of independent companies have been formed, by which the vast territory, from the Atlantic Ocean to the Mississippi, and from the Gulf of Mexico to the frontiers of Canada, is overspread with a net-work of wires, upon which intelligence of every description, and personal and commercial correspondence are flowing night and day incessantly from year's end to year's end in a torrent of which the old continents offer no similar example. It is almost impossible to ascertain, even with a tolerable degree of approximation, the actual extent of wires which at any given time are in operation. When we commence an investigation of the statistics, with a view to the collection of facts necessary to form the basis of a report, we are overwhelmed with statements of lines commenced, lines half completed and nearly completed, and many which undoubtedly must be completed before our report can come under the eyes of our readers. All that can be done in such a case is to give the nearest practicable estimate of the extent of these enterprises at a given epoch, indicating in a general manner such as are in progress and likely sooner or later to be completed and brought *into* practical operation.

The American lines are generally classified according to the telegraph instruments with which they work. These are those of Morse, House, and Bain, all of which transmit despatches by means of a single conducting wire, and all of which write or print the despatches they transmit, those of Morse and Bain, in a telegraphic cipher, and that of House in the common Roman capitals.

Of these three systems, that of Morse is in the most general use—a circumstance which is partly explained by the fact, that it was the earliest adopted, and had established its ground long before either of the competing systems. It must be admitted, that so far as public opinion and favour can be accepted as a test of practical excellence, the system of Morse has received not only a large majority of the suffrages in the United States, but also in the northern and eastern states of Europe.

According to a report published in 1853, the total length of telegraphic wire, at the end of 1852, then in operation in the United States, was 24375 miles, which was distributed between the three systems of telegraphs in the following proportion:—

	Miles
Morse	19963
House	2400
Bain	2012
	24375

It appears by a more recent estimate, published in a report presented by Mr. T. P. Shaffner to the Telegraphic Convention, that in March, 1854, the total extent of telegraphic wire then in operation was above 40000 miles, which were thus distributed:—

	Miles.
Morse	36972
House	3850
Bain	570
	41392

The decrease of the extent of the Bain lines was owing to the coalition of some of the most extensive of them with the Morse companies.

It would thus appear that in little more than twelve months the increase of telegraphic wire amounted to 17000 miles. It is probable, however, that the estimate which we have quoted of the extent in operation at the end of 1852 may have been below the *actual* length.

The following estimate of the capital absorbed by these enterprises is given in Mr. Shaffner's report:—

	Dollars.
Morse lines . . .	5,545800
House	955000
Bain	171000
	6,671800

Being equivalent to 1,400000*l*.

Except in cases where a great commerce or intercourse prevails, each company maintains only a single conducting wire between station and station. As examples of the exceptions to this may be mentioned, Washington and Philadelphia, connected by seven Morse wires; New York and Buffalo, and New York and Boston, by three; Cleveland and Cincinnati, and Boston and Portland, by two.

In some cases, important terminal stations, such as New York and Boston, are connected by the wires of several competing companies, which follow, however, different routes, serving different intermediate stations.

The State of Ohio, a tract of country lying between the upper part of the river of that name, and the southern shore of Lake Erie, the chief part of which, within the lives of the present generation, was an uncultivated and uninhabited waste, is now overspread with between 3000 and 4000 miles of electric telegraph.

286. Stupendous as have been the projects actually realised in this application of science to the social uses of the United States, they sink into comparative insignificance when others, which are contemplated, and likely to be executed, are stated. Thus we find a report presented to Congress, in the session of 1851, by the Post-office Committee, in which a project of a line of electric telegraph to California is recommended for ultimate adoption. This report says that—

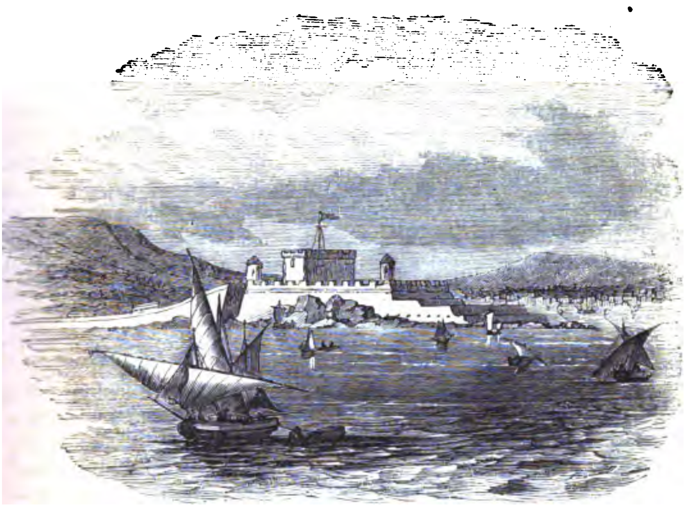
"The route selected by the committee is, according to the survey of Captain W. W. Chapman, U.S. Army, one of the best that could be adopted, possessing as it does great local advantages. It will commence at the city of Natchez, in the State of Mississippi, running through a well settled portion of Northern Texas, to the town of El Paso, on the Rio Grande, in latitude 32°; thence to the junction of the Gila and Colorado rivers, crossing at the head of the Gulf of California to San Diego, on the Pacific; thence along the coast to Monterey and San Francisco. By this route, the whole line between the Mississippi River and Pacific Ocean will be south of latitude 33°; consequently, almost entirely free from the great difficulties to be encountered, owing to the snow

and ice on the northern route, by the way of the South Pass, crossing the Sierra Nevada Mountains in latitude 39°. The whole distance from the Mississippi to San Francisco will be about 2400 miles.

"In a commercial point of view, the line in question assumes a gigantic importance, and presents itself not only in the attitude of a means of communication between the opposite extremes of a single country, however great, but as a channel for imparting knowledge between distant parts of the earth. With the existing facilities, it requires months to convey information from the sunny climes of the East to the less favoured, in point of climate, but not less important regions of the West, teeming as they do with the products of art and enterprise. Let this line of wires be established, and the Pacific and Atlantic Oceans become as one, and intelligence will be conveyed from London to India in a shorter time than was required ten years since to transmit a letter from New York to Liverpool.

"Nor does the importance of the undertaking claim less interest, when regarded in a social point of view. California is being peopled daily and hourly by our friends, our kindred, and our political brethren. The little bands that a few centuries since landed on the western shores of the Atlantic, have now become a mighty nation. The tide of population has been rolling onward, increasing as it approached the setting sun, until at length our people look abroad upon the Pacific, and have their homes almost within sight of the spice groves of Japan. Although separated from us by thousands of miles of distance, they will be again restored to us in feeling, and still present to our affections, through the help of this noiseless tenant of the wilderness."

A company is stated to be organised for carrying out this vast project, with a capital of 5,000000 dollars.



SPEZZIA,

THE ITALIAN TERMINUS OF THE MEDITERRANEAN SUBMARINE TELEGRAPH LINE.

THE ELECTRIC TELEGRAPH.

CHAPTER XV.

287. Telegraphic lines in British America.—288. Belgian lines.—289. Their extent and cost.—290. Correspondence transmitted on them.—291. Large proportion of foreign despatches.—292. Classification and proportion of despatches.—293. Tariff.—294. Paris telegraphic congress and convention.—295. Telegraphic instruments used in Belgium.—296. Language of despatches.—297. French telegraphic lines.—298. Instruments used on them.—299. Their connection with those of other states.—300. Repetition necessary at intermediate stations.—301. Case of despatches between France and England.—302. Advantages of increased number of wires.—303. Of instruments requiring only one wire.—304. Organisation of the French telegraphic administration.—305. Austro-Germanic Union.—306. Stations and tariff.—307. Netherlands telegraphic lines.—308. Swiss telegraphic lines.—309. Italian telegraphic lines.

TELEGRAPH LINES IN BRITISH AMERICA.

287. The length of lines of electric telegraph in operation in British America in 1853, was about 1000 miles.

Mr. Joseph Whitworth, as one of the British Commission sent to the New York Exhibition of 1854, presented a report to

Parliament, which has been published, and which supplies some interesting particulars.

According to Mr. Whitworth, the most distant points connected by electric telegraph in North America are Quebec and New Orleans, which are 3000 miles apart, and the network of lines extends to the west as far as Missouri, about 500 towns and villages being provided with stations.

There are two separate lines connecting New York with New Orleans, one running along the sea-board, the other by way of the Mississippi, each about 2000 miles long. Messages have been transmitted from New York to New Orleans, and answers received, in the space of three hours, though they had necessarily to be written several times in the course of transmission.

When the contemplated lines connecting California with the Atlantic, and Newfoundland with the main continent, are completed, San Francisco will be in communication with St. John's, Newfoundland, which is distant from Galway but five days' passage. It is, therefore, estimated that intelligence may be conveyed from the Pacific to Europe, and *vice versâ*, in about six days.

The cost of erecting telegraph lines varies according to localities, but the expenses upon the whole are estimated to average about $180 (36*l.*) per mile throughout the States; the moderate amount of this estimate is, in a great measure, to be attributed to the facilities afforded by the general telegraph laws for the formation of companies and the construction of lines.

The electric telegraph is used by all classes of society as an ordinary method of transmitting intelligence.

Government despatches, and messages involving the life or death of any persons, are entitled to precedence, next come important press communications, but the latter, if not of extraordinary interest, await their regular turn.

The leading newspapers of New York contribute jointly towards the expenses of daily telegraphic communications. The annual sum paid by the "Associated Press" averages $30,000 per annum.

The following is the tariff for the press despatches:—

	Under	200	miles,	1	cent	per word.
Between	200	and	500	,,	2	,,	,,
,,	500	,,	700	,,	3	,,	,,
,,	700	,,	1000	,,	4	,,	,,
,,	1000	,,	1500	,,	5	,,	,,
,,	1500	,,	over	,,	6	,,	,,

Assuming three cents as the average, the total amount of matter received by telegraph for the "New York Associated Press" amounts to a million words per annum, or about 600 columns

of a London newspaper of the largest size, averaging almost two columns per day.

Supposing six papers to be associated together, the share of each would annually amount to about $5000, or 1000*l*., for two columns of telegraphic intelligence daily.

Commercial men use the electric telegraph in their transactions to a very great extent. In 1852 there were transmitted by one of the three telegraph lines that connect New York and Boston, between 500 and 600 messages daily. The sums paid on this line by some of the principal commercial houses who used it averaged in 1852 for each from $60 (12*l*.) to $80 (16*l*.) per month.

On other lines the leading commercial houses were estimated to pay from $500 to $1000 (100*l*. to 200*l*.) per annum for telegraphic despatches.

Interruptions occur most frequently from the interference of atmospheric electricity; in summer they are estimated to take place on an average twice a week, but many contrivances have been adopted for obviating this inconvenience, such as lightning arrestors, &c., which are generally known; the number of interruptions have been thereby reduced about 30 per cent.

Other accidental causes of interruption occur irregularly from the falling of the poles, the breaking of the wires by falling trees, and, particularly in winter, from the accumulated weight of snow or ice.

The electric current is made to act through long distances, by using local and branch circuits, and relay magnets, in those systems where it would be otherwise too weak to operate effectually.

In Mr. Bain's system, a weak current is found sufficient for very long distances; between New York and Boston, a distance of 270 miles, no branch or local circuit is required. In some cases, where both Morse's and Bain's telegraphs are used by an amalgamated company in the same office, it is found convenient, in certain conditions of the atmosphere, to remove the wires from Morse's instruments, and connect them with Bain's, on which it is practicable to operate when communication by Morse's system is interrupted.

It is generally believed that by laying insulated wires underground the interruptions will be reduced so as to be altogether inconsiderable. The expense of the process, however, is regarded as a great impediment in the United States, where cheapness of construction is an object of the highest consideration.

The application of the electric telegraph is not confined to the transmission of messages from one part of the States to another: in the form of a local or municipal telegraph, it is employed as an important instrument of regulation and intelligence in the internal administration of towns.

No adaptation of the system can be more interesting and useful than that which is made for the purpose of conveying signals of alarm and intelligence in the case of fire.

This system has been very completely developed in Boston.

The city is divided into seven districts, each provided with a powerful alarm bell. Every district contains several stations, varying in number according to its size and population. There are altogether in the seven districts forty-two stations. All these stations are connected with a chief central office, to which intelligence of fire is conveyed, and from which the alarm is given; two telegraph wires are employed, a return wire being used to complete the circuit, and provide as completely as possible against accidental interruption or confusion.

At each of the forty-two stations, which are placed at intervals of 100 rods throughout the city, there is erected in some conspicuous position a cast-iron box containing the apparatus for conveying intelligence to the central office. The box is kept locked, but the key is always to be found in the custody of some person in the neighbourhood, whose address is painted on the box door.

On opening this door, access is gained to a handle which is directed, by a notice painted above it, to be turned slowly several times. The handle turns a wheel that carries a certain number of teeth, arranged in two groups, the number of teeth in one representing the district, in the other, the station; those teeth act upon a signal key, closing and breaking the circuit connected with the central office, as many times as there are teeth in the wheel. Signals are thus conveyed to the central office, and, by striking the signal bell a certain number of times, the district and station from which the signal is made is indicated.

An attendant is always on the watch at the central office, and on his attention being called to the signals by the striking of a large call bell, he immediately sets in motion his alarm apparatus, and by depressing his telegraph-key, causes all the alarm bells of the seven districts to toll as many times in quick succession as will indicate the district where the fire has occurred, the alarm being repeated at short intervals for as long a time as may be necessary.

The signal-boxes erected at the stations contain, in addition to the signal-handle, a small electro-magnet, an armature, and a signal-key, so that full and particular communications can be made between each box and the central station, the clicks of the armature forming audible signals. They have also an apparatus called a "Discharger of Atmospheric Electricity," for preventing the occurrence of injuries during thunderstorms.

By this system certain information is given to the central office

at the earliest possible moment of the exact locality in which a fire may have broken out, and the alarm is immediately spread over the entire city.

Every one who is aroused by the alarm is enabled to tell at once whether interest or duty calls him to the scene of action, and the exact point to which assistance is summoned. Should the alarm be given in the night, those whose attention is awakened may ascertain from the tolling of the bell the precise quarter in which danger threatens, and should they have been needlessly disturbed, may rest in peace, and find in the knowledge that they and theirs at least are in safety, a consolation for broken slumbers.

Telegraph wires in towns are almost universally carried along the tops of houses, or on poles erected in the streets, instead of being conveyed in pipes underground. So little difficulty is met with on the part of proprietors of houses, that telegraph lines are in some cases erected by private individuals for their own particular use. As an instance, may be mentioned the case of a large manufacturer in New York, who has an office in one part of the city, while his works lie in a contrary direction. In order to keep up a direct communication between both, he has erected a telegraphic wire at his own expense, and carried it over the tops of the houses intervening between his office and his works, having obtained without any trouble the permission of their various owners.

BELGIAN TELEGRAPH LINES.

288. Although in the extent of its territory Belgium is one of the least considerable of the Continental States, it derives from its position in relation to this country, much importance, so far as regards telegraphic communications. By the submarine cable between Dover and Ostend, or failing that, by the cable between Dover and Calais, Belgium constitutes the most direct stage in the telegraphic route to the Northern States.

The Belgian telegraph lines, as well as the railways, are constructed, maintained, and administered by the state. Separate systems of conducting wires are appropriated to the service of the railways, which is performed exclusively with the alphabetical apparatus of M. Lippens, already described (202). There are a few exceptional cases on branch lines of railway, upon which the state has not yet constructed telegraphs for the public service, where private despatches are sent by the railway telegraphs, but generally an extensive system of independent wires, with their accessories, are adapted to this purpose, for which a large corps of telegraphists has been formed.

289. The state telegraph lines, appropriated to the public service, have at present (1854) a total length of about 550 miles, upon which about 16000 miles of wire have been erected. With the exception of some short distances through Brussels, these wires are everywhere supported on posts.

The total capital absorbed in this establishment is estimated at 23000*l.*, and the gross annual receipts in 1854, were computed at 10000*l.*,* of which the net profit was 3600*l.*, being nearly 16 per cent. of the capital.

Immediately on the completion of the submarine cable between Dover and Ostend, an active daily intercourse between London and Brussels commenced, and has since been sustained. The connections were completed on the 20th June, 1853, and on the 27th of the same month, 111 despatches were interchanged between the two capitals.

It is proposed to construct wires and apparatus sufficient to maintain the communications on this important line, so that even with the greatest pressure of business, the public shall not have reasonable ground of complaint on account of delay. "A telegraphic line," observes the Minister of Public Works, "should not be organised with the mere powers which suffice for the ordinary or average business, but should be such as to meet the exigencies of occasional pressure, without subjecting the public to delay, or interrupting other regular business. Besides which, it ought never to be forgotten, that in telegraphic business great pressure must always come at particular hours, when prompt expedition is indispensable. This will be easily understood in the business of the Belgian lines, which constitute the route upon which the quotations of the money markets of all the great centres of affairs—London, Paris, Amsterdam, Berlin, Antwerp, &c.—are transmitted at certain hours."

290. The business transacted by the Belgian telegraphs consists of three classes of despatches.

HOME DESPATCHES, being those transmitted between two Belgian stations.

INTERNATIONAL DESPATCHES, being those between a Belgian and Foreign station.

FOREIGN DESPATCHES, being those transmitted through Belgium in passing between two foreign stations.

Of these three classes of telegraphic business, the second has proved to be the greatest in number, and the third the most productive, as appears by the following statement of the results of the year ending 31st December, 1853.

* Report of Minister of Public Works to the Chamber, Feb. 14, 1854.

Despatches.	Number of despatches.	Receipts.	Number per cent. of total.	Receipts per cent. of total.
Home . . .	14160	£1813	27·2	16·7
International . .	20664	3831	39·7	35·2
Foreign . .	17232	5227	33·1	48·1
Total	52056	£10871	100·0	100·0

291. It appears from this statement that about 40 per cent. of the despatches transmitted and received in Belgium, are interchanged with foreign countries, and that one-third of all that passes on Belgian wires is matter passing *en route* between foreign places. Nearly half the gross amount received for telegraphic despatches is produced by despatches transmitted between foreign stations, and only passing *en route* through Belgium. This is explained by the fact that such despatches passing always from frontier to frontier, and in the majority of cases from Ostend to the Prussian frontier, the entire length of the kingdom, pay for the longest class of telegraphic distance. This is one of the advantages which the Belgian telegraph derives from the geographical position of the country.

292. To show the proportion in which the telegraphic service is shared by different subjects of correspondence, we shall take the classified subjects of dispatches of August, 1853, the month in which the correspondence was most active. In this month there were 5799 despatches transmitted on the Belgian wires, which are thus classified:—

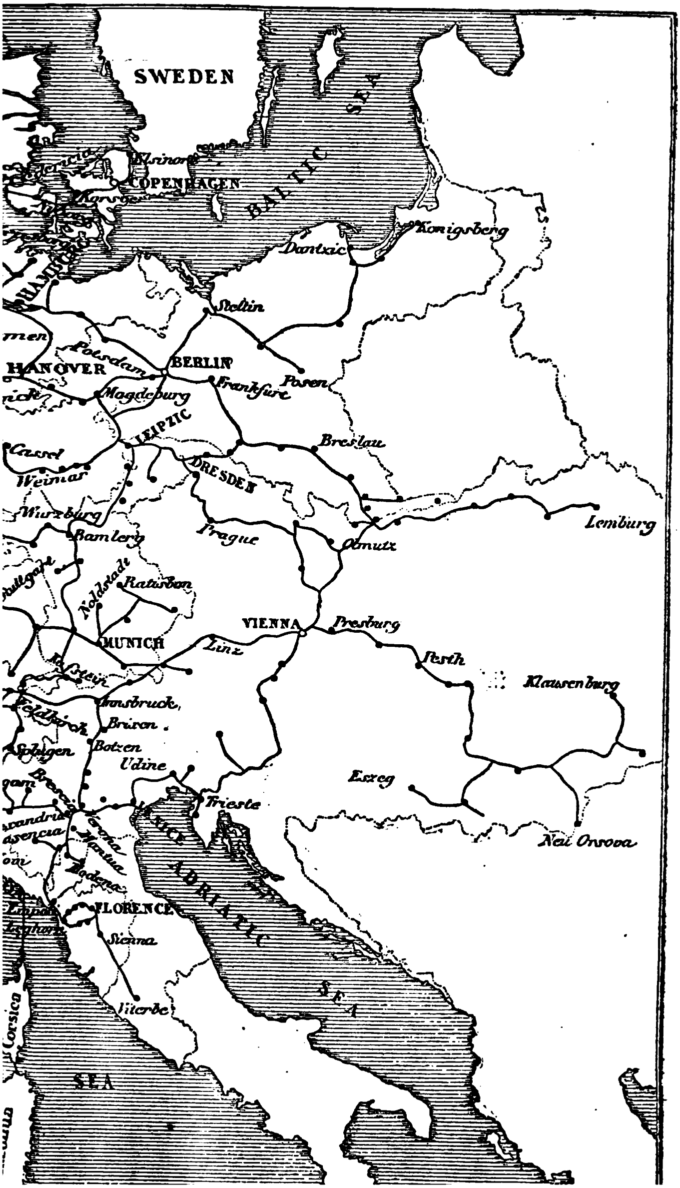
	Number.	Per cent. of Total.
Commerce	3247	56
Money market . . .	1566	27
Private	754	13
Press	116	2
Government . . .	116	2
Total	5799	100

In relation to length the proportion was as follows:—

	Number.	Per cent. of Total.
From 1 to 20 words .	4741	81·8
From 21 to 50 words . .	921	15·9
From 51 to 100 words .	122	2·1
Above 100 words . . .	15	0·2
Total	5799	100·0

TELEGRAPHIC MAP.—In the annexed Map is presented a General View of the Telegraphic Network

BY WHICH EUROPE WAS OVERSPREAD AT THE CLOSE OF THE YEAR 1854.



Thus it appears that commerce and the Stock Exchange supply 83 per cent. of the whole telegraphic business, 13 per cent. being personal and domestic, and the press and government each employing the insignificant proportion of one despatch in every fifty.

It is also apparent, that a very small proportion of the despatches exceed the length of 20 words, and almost none that of 50 words.

293. According to the Belgian tariff, messages not exceeding 20 words are charged 2*s*. for distances not exceeding 60 miles; 4*s*., from 60 to 140 miles; and 6*s*. above 140. No distances within the limits of Belgium exceed 200 miles.

For messages of 21 to 50 words the charges are doubled, and for 51 to 100 words are tripled.

It will be seen that these charges are more than double the corresponding charges on the English lines.

294. The large proportion of international and foreign despatches transmitted upon the Belgian wires, and the necessity of prepayment for despatches, in all cases, to their ultimate destinations, rendered it necessary for the Belgian administration of telegraphs to make some general arrangement with the principal contiguous states, for such an interchange of correspondence. A telegraphic congress was accordingly convened at Paris, in September, 1853, which was attended by delegates from France, Belgium, Prussia, Austria, and the minor German States. A telegraphic convention was concluded and signed on the 4th of October, 1852, fixing definitely a general tariff for all despatches transmitted to or from the several States.

According to this convention, each telegraphic region was divided into a series of zones, measured from the Belgian frontier, according to a series of direct distances (as the bird flies), the charges to places in each successive zone, for single despatches (1 to 20 words), being fixed at 2*s*., 4*s*., 6*s*., 8*s*., and so on, an increasement of 2*s*. being made for each increase of distance.

France is, by this convention, resolved into six telegraphic zones, the tariff for single messages being 2*s*., 4*s*., 6*s*., 8*s*., 10*s*., and 12*s*. The first zone includes the chief northern towns, Arras, Douai, Lille, and Valenciennes; the second, Amiens, Boulogne, Dunkerque, &c.; the third, the chief places in the nearer central parts, including Paris, Orléans, Havre, &c.; the fourth, the more distant central parts, such as Châlons, Lyons, Strasbourg, &c.; the fifth, the nearer southern parts, Avignon, Grenoble, Bordeaux, &c.; and the sixth, the most remote southern parts, Marseilles, Bayonne, &c.

The German States, including Lombardy, are resolved into *eight* zones, of which the tariff is 2*s*., 4*s*., 6*s*., 8*s*., 10*s*., 12*s*., 14*s*., and 16*s*. These zones include the whole extent of Northern and

Eastern Europe beyond the Rhine, as well as the north-eastern part of Italy.

The tariff for single messages crossing the channel, by the Ostend submarine cable, is 8*s*. For these charges, however, they are transmitted, if required, to London.

295. At the chief stations on the Belgian lines, the double needle instruments, as used in England, the French State instruments, and the Morse telegraph, as used in the German States, are provided. By the first the telegraphic correspondence with England, by the second with France, and by the third with the German States, is carried on.

296. It is intended generally to receive and transmit despatches written at the option of the sender, either in French, German, or English, at all the Belgian stations; but for the present this is only done at Brussels, Antwerp, and Ostend.

Despatches transmitted between Holland and Belgium can be transmitted and received in Dutch, and all despatches between Belgian stations may be sent in Flemish. At all stations despatches are transmitted and received in French.

If the place to which a despatch is addressed be not a telegraphic station, the despatch will be forwarded to its destination either by post or by a special messenger, at the option of the sender. If the former, the postage is 10*d.*, if the place be within the State where the telegraphic station at which the despatch arrives is situate, and 20*d.*, if in another State. If the latter, a charge of 10*d.* is made for a distance of a kilomètre (five furlongs), and 5*d.* for every additional kilomètre.

FRENCH TELEGRAPHIC LINES.

297. Although late in the adoption of this improved agency of intercommunication, France, having once commenced, has prosecuted the work with great vigour, and the country is now overspread with a net-work, the extent of which, in actual operation at the close of the present year, 1854, will not be less than 6000 miles. This system is everywhere erected upon posts chemically injected to insure their durability, and there are nowhere less than two conducting wires; but a greater number between all stations where an active correspondence is maintained.

298. The instruments used for the transmission of all home despatches, that is, all despatches transmitted between any two French stations, are the French State telegraphs, explained in (183). For international dispatches, the double needle and Morse's instruments are used. These instruments are provided at the central station, in the Ministry of the Interior at Paris. The double needle instruments are provided also at Calais, and

Morse's instruments at Strasbourg. As the system is developed and extended, the double needle instruments will be provided in addition to the French telegraphs, at all stations which may be in direct communication with England, and Morse's instruments at all stations which may be in direct communication with the German States.

299. The French telegraphic lines communicate with those of England at Calais by the submarine cable; with those of Belgium at Lille and Douai; with those of Prussia and Northern Germany, at Metz; with the Rhenish States, Wirtemburg, Bavaria, and Austria, at Strasbourg; with those of Switzerland, at Mulhouse and Mâcon, the former communicating with Bâle, and the latter with Geneva; and, in fine, with those of Savoy and Piedmont, at Grenoble.

Other links of electric connection will speedily be formed. Thus the present lines are continued to the Spanish frontier at St. Sebastian, and lines of wire are now being laid between that place and Madrid, so that the capital of Spain will be in electric connection with that of France, and therefore also with London, and the other capitals of Europe, most probably, before these pages are in the hands of the reader.

300. In practice the transmission of despatches is not always so direct or immediate as it would appear to be upon the inspection of a telegraphic map. Thus, by the submarine cable between Dover and Calais, Paris is in permanent direct communication with London. But when it is desired to transmit a despatch from Paris to any of the provincial towns of England, the despatch is at present received and written down at the central station in London, and then repeated and transmitted to the place of its destination in the provinces. This repetition could of course be avoided, by uniting, in the London station, the wire from Paris with the wire leading to the provincial station to which the despatch is addressed, and if the despatch were one of extraordinary length this course would be the most expeditious; but to adopt it with the ordinary class of short messages, would involve much inconvenience and more delay in general than is incurred by its repetition and retransmission. Thus, to send each message direct to its destination in the provinces, it would be necessary that, previously to the transmission from Paris, notice should be transmitted to London to connect the Paris wires with those between London and the place of destination, and as this change would have to be made separately for every provincial message, and as the wires between London and the various provincial stations must necessarily be occupied, more or less, at all times, in the transmission of home correspondence, the business of trans-

mission in this direct manner would not only be far more dilatory than the process of repetition, but would, in fact, at busy times of the day be totally impracticable.

301. What has been here stated respecting the Paris and London line will be applicable, *mutatis mutandis*, not only to all international messages, but in many cases to messages transmitted between home stations, which it is often more convenient and expeditious to repeat and retransmit at certain intermediate stations than to send direct by the connection of the wires at those stations.

302. It will be understood, nevertheless, that the necessity for this circuitous transmission, and intermediate repetition of despatches, arises in all cases from the insufficiency of the number of conducting wires in relation to the quantity of correspondence to be transmitted. In the transmission of each despatch by the English and French instruments, two wires are employed. Now, if the direct correspondence between London and Paris, during the most busy hours of the day, be sufficient to employ one pair of conducting wires, another pair would be necessary to communicate with intermediate places, and if the correspondence with these were very unequal, some engrossing a large share of it, a third pair might be required, and so on.

303. It must be, therefore, very apparent that great convenience would in such cases be gained by substituting, for the English and French telegraph, that of Morse or Bain, or any other which transmits by a single conducting wire. In that case, the four wires contained in the submarine cable, between Dover and Calais, would do much more than double their present duty. Instead of carrying two streams of messages simultaneously, as they do at present, they would carry four. If one were put in permanent connection with London and Paris, the three others could be reserved, one for direct connection with chief provincial towns, such as Birmingham, Manchester, Liverpool, Glasgow, Dublin, &c., and the two others for messages to less important stations, subject to occasional repetition. These latter would be to the telegraphic line what the second and third class trains are to the railway. It might be found even advantageous to fix a higher price of transmission for messages thus sent without intermediate repetition, just as a higher fare is paid for express than for ordinary trains.

304. The French government has recently re-organised the administration of the telegraphs throughout its entire territory, and besides modifying and reducing the tariff, it has placed the whole upon a more efficient footing. It now constitutes an important department of the state, placed under the superintendence of a director-general, four inspectors-general, twelve chief directors, and an hundred inspectors. The director-gener

to the construction of telegraphic lines, an extensive net-work of which has been constructed and brought into operation. Thus Berne is connected with the French lines by wires to Besançon, and with the German lines at Bâle. Lausanne is connected with Besançon by an independent line, and also with Berne on one side and Geneva on the other. Geneva is also connected with the French system at Mâcon, and with that of Savoy at Aix, from whence a line of wires is carried across Mont Cenis to Turin.

From Lausanne the wires are carried by Vevay and Sion through the Valais to the foot of the St. Gothard, across which they are continued by Bellinzona to Milan.

Another line passes from Bâle by Lucerne, Glaris, and Coire, to the Splügen, which it crosses, and is carried to meet the former line at Bellinzona, and thence to Milan.

Another line from Bâle passes by Zurich and St. Gal to Innspruck, from whence it passes by Batzen and Trente to Verona, and by Salzburg and Linz to Vienna.

Lines have, however, been since constructed, including some other stations.

ITALIAN TELEGRAPHIC LINES.

309. Italy is put in electric connection with the more northern countries of Europe at six points, Nice, Mont Cenis, the St. Gothard, the Splügen, the Tyrolese Alps, through Innspruck, and by Trieste.

The French lines are already extended to Nice, and a line between Nice and Turin will probably be completed before these pages come into the hands of the reader. The French and Swiss lines are connected with Turin by the wires over Mont Cenis already mentioned; the Swiss and Rhenish lines, with Milan by the wires over the St. Gothard, and the Splügen and the Austrian and Bavarian lines by the wires over the Tyrolese Alps, and those from Trieste round the shores of the Gulf to Venice.

From Venice to Milan a line is carried by Verona and Brescia, which is continued to Turin. From this line there are two branches going southwards, one from Verona by Mantua, Parma, Modena, Lucca, Leghorn, Florence, Sienna to Viterbo in the Papal States. This line will speedily be continued to Rome. The other branch goes from Alexandria to Genoa.

Such is the extent of Italian telegraphs completed in 1854.

LISBON AFTER THE EARTHQUAKE OF 1755, REDUCED FROM AN ENGRAVING, DATED 1756, IN THE IMPERIAL LIBRARY AT PARIS.

EARTHQUAKES AND VOLCANOES.

CHAPTER I.

1. Science tends to the discovery of general laws—admits no accidental phenomena.—2. Atmospheric phenomena neither uncertain nor accidental.—3. Physical subterranean agencies.—4. Convulsions incidental to the solid shell of the earth.—5. Increase of temperature at increasing depths.—6. Central parts in a state of fusion.—7. Depth at which this liquid state commences.—8. Proportional thickness of the solid shell.—9. Surface of the earth subject to frequent convulsions from the reaction of the internal fluid matter on the solid shell. —10. Geological evidences of this.—11. Physical causes of earthquakes and volcanoes.—12. Undulations of surface produced by the internal fluid.—13. Their effects on buildings and other objects.—14. Vertical and oscillatory motions.—15. Undulations propagated

in parallel lines—sometimes in circles.—16. Effects of the vertical shock in the earthquake of Riobamba.—17. Examples of circular propagation.—18. Examples of horizontal and gyratory derangement. —19. Strong shocks sometimes felt without overturning buildings.—20. Gyratory earthquakes most destructive.—21. Singular displacement at Riobamba.—22. Earthquakes are not generally attended by any peculiar atmospheric prognostics.—23. Earthquakes most frequent at the equinoxes.—24. Well described by Pliny and Seneca.—25. Attended by subterranean thunder.—26. Character of these sounds. —27. Are heard at great distances from the place of the earthquake. —28. Examples of this.—29. Subterranean roaring of Guanaxuato. —30. Their effects on the inhabitants.—31. Great extent over which earthquakes spread.—32. They affect the bottom of the ocean.—33. Curious examples of these effects.

1. It is the tendency of undisciplined minds to refer all unusual and occasional phenomena to local and accidental causes, and, mistaking trivial and unimportant differences for essential distinctions, to ascribe to very different physical agencies what are only various effects proceeding from the operation of a single principle. The tendency of science is the reverse. It ignores accident in nature. It admits no contingencies. The Architect of the universe operates by fixed and general laws, the results of which are uniform and regular. The apparent uncertainty of some natural phenomena arises merely from our imperfect knowledge of the laws which govern them. Before the science of astronomy had reached a certain degree of advancement, solar and lunar eclipses were regarded as preternatural manifestations, during which the common laws of nature were suspended, and as the forerunners of terrible calamities to the human race. Now that the laws which govern the motions of the heavenly bodies are known, these phenomena have lost their terrors. They are no longer regarded as either preternatural, uncertain, or accidental. They are, on the contrary, as regular, periodical, and certain as the seasons, or the returns of light and darkness; and the times of their occurrence, and all the circumstances attending them, are predicted with the greatest conceivable certainty and the last degree of precision.

2. Nothing is more usual than to apply the term "uncertain" to the weather, yet nothing can be more absurd. The causes which govern its phenomena being physical agencies independent of the will or interference of any being, save of Him "who rules the storm," are as fixed and as certain in their operation, and as regular in the production of their effects, as those which maintain and regulate the motions of the solar system. The moment of the rising or setting of the sun on any given day of the ensuing year, is, therefore, *in the nature of things*, not more certain than

the atmospheric phenomena which will take place on that day. The doubt and uncertainty which attend these events belong altogether to our anticipations of them, and not to the things themselves. If our knowledge of meteorology were as advanced as our knowledge of astronomy, we should be in a condition to declare the time, duration, and intensity of every shower, which shall fall during the ensuing year, with as much certainty and precision as we are able to fortel the rising, setting, and southing of the sun and moon, or the rise and fall of the tides of the ocean.

3. If our knowledge of the laws which govern the movements of the aërial ocean which floats above the crust of the earth be obscure and imperfect, it is infinitely more so of those which rule the matter which lies below that crust. Yet what various and apparently different and unconnected phenomena are governed by these undiscovered laws, which, through ignorance of them, have been regarded as arising from local, accidental, and totally independent and different agencies. Earthquakes, volcanic eruptions, the production and submersion of islands, the issue of gases such as sulphurous and carbonic acid from fissures in the earth, hot springs, eruptions of warm mud, the increase of temperature at increasing depths, the origin of mountain chains, such as the Andes, the Pyrenees, the Alps, and the Himalaya, the alternate elevation and submersion of vast continents, the variations of the configuration of the land, and the distribution of the waters on the surface of the globe, all these so apparently different phenomena, it has been the triumph of science to trace to a common origin, the reaction of the matter confined within the earth against its external shell.

4. It is our present purpose briefly to explain the physical conditions out of which these stupendous phenomena arise, and to describe the characters and circumstances which attend them. With this view, it will be necessary first to state what is known, either by observation or inference, respecting the condition of that part of the earth included within the solid shell, the external surface of which is the habitation of the human race, and other organised tribes, and to explain generally what have been at past epochs and at the present time the chief effects produced by the reaction of the matter thus confined upon the crust which encloses it.

When it is considered that the actual distance of the surface from the centre, or the length of the terrestrial radius, is more than twenty millions of feet, and that the utmost depth to which we have been able to descend in boring or mining operations has not much exceeded two thousand feet, that is the ten-thousandth part of the entire radius, it will be apparent that the data

supplied by so scanty a range of observation must be very limited. Less direct sources of observation, though not less certain and precise, have, however, been opened by the researches of geologists, who have shown that the crust of the earth fractured by eruptions produced by forces acting from the interior outwards has been exposed to view, so that the condition of the external shell, to a depth of about forty thousand feet, or the five-hundredth part of the entire distance from the surface to the centre, can be ascertained.

5. From what has been explained in former numbers of this series, in which the subject of terrestrial heat has been considered, it will be seen that extended and general thermometric observations made in mines and other deep excavations, and on the temperature of water rising in Artesian wells, prove that in descending to greater and greater depths into the crust of the earth, there is a constant and regular increase of temperature at the rate of about one thermometric degree for every fifty feet of depth, or what is nearly the same, an increase at the rate of 100° per mile.

6. Now supposing this law of increase to continue without interruption downwards, it would follow that at the depth of forty miles, or the hundredth part of the distance from the surface to the centre, a temperature of 4000° prevails. It is certain that no part of the matter composing the crust of the earth could remain solid at such a temperature, being higher than those at which the most refractory bodies are fused.

7. No great degree of precision in the numerical data on which this calculation is based is necessary to establish the conclusion to which it leads. Whatever be the exact rate at which the temperature is augmented in descending, it is beyond all doubt that at a depth of thirty or forty miles it must be such as to reduce to the state of an incandescent liquid the most refractory bodies which enter into the composition of the earth.

This liquid fire must extend to the very centre of the globe, and from the well understood properties of fluidity, it may be considered certain that an uniform temperature is maintained throughout the liquid mass thus enclosed within the solid spheroidal shell.

Now let us pause for a moment to consider the consequences to which this leads, and to contemplate the spectacle which it offers of the condition of our terrestrial dwelling.

8. Let us take the extreme estimate of forty miles as the depth below which the matter composing the earth is completely liquified. This depth is the one-hundredth part of the terrestrial radius.

We are then to regard the earth as a spherical shell of solid matter filled with liquid fire. The thickness of this shell being in

the proportion to its diameter just stated, it will be represented by the black circle surrounding fig. 1.

If the egg of a fowl or an ostrich be imagined to represent the earth, its shell would be much too thick to represent its solid crust!

Fig. 1.

It is no rhetorical exaggeration, then, to affirm that the globe we live on is a stupendous but very thin bombshell charged with liquid fire! If such be the case, it may naturally be asked how it happens that so thin a crust, supported on so mobile a fluid, can maintain that general state of stability and equilibrium which characterises the surface of the earth, so that it is referred to in times ancient and modern as the type of all that is most solid and durable?

9. To this it may be answered that many phenomena with which mankind in certain localities is only too familiar, and which are known to all by authentic contemporary reports and historical records, prove that this imputed stability cannot be admitted without most serious qualifications and exceptions. Not a year passes that earthquakes are not reported in various parts of the

earth. Not a century passes that these terrible phenomena are not occasionally developed with such an energy and extent that vast tracts of country are laid waste, cities and towns destroyed, and thousands of human beings buried beneath their ruins. Volcanic eruptions are permanent indications of subterranean agencies, modifying more or less the surface. Torrents of lava and clouds of ashes ejected from them cover surrounding regions, and sometimes entomb entire cities. The solid bottom of the ocean is occasionally heaved upwards by a force from below, so as to form new islands, which sometimes subsiding are again submerged. These and countless other phenomena show that the crust of the globe is not so solid and unchangeable as it is generally assumed to be.

10. But if, instead of confining our view to that comparatively brief interval in the life of the earth limited by the existence of the human race, and the other organised tribes animal and vegetable, which now prevail upon it, we extend our enquiries over those periods of the past, far more vast, with which the discoveries of astronomers and geologists have made us to some extent familiar, we shall find monuments and records of physical changes produced by eruptive forces emanating from the central parts, on a scale so prodigious, that compared with them, the most devastating earthquakes and volcanic eruptions are utterly insignificant. The central fluid matter pressing unequally on its confining shell, has at various times cracked it in different directions, and the molten mineral matter, issuing from the fissures, and gradually cooling, taking first a pasty and semifluid consistency, and afterwards solidifying, has formed mountain chains over the fissures. Such has been the operation by which the vast ridges of the Andes, which traverse the new continent from north to south, and those of the Alps and Himalaya, which traverse the old continents from east to west, have been formed.

11. Postponing, however, for the present all notice of those physical revolutions of which the date is prior to the creation of the present inhabitants of the earth, we shall limit our observations to the circumstances which produce and attend the principal convulsions of nature which have manifested themselves in historical times, and which must be traced to the reaction of the interior fiery fluid upon the thin solid shell of the earth.

That fluid, like the waters of the ocean, is subject to undulation. If its undulations be so limited in their play that the materials of which the terrestrial shell is formed have sufficient elasticity to yield to their pressure without being fractured, they will produce on the exterior surface of that shell corresponding undulations by which all bodies placed upon its surface must be

affected, as a floating body is by the waves of the ocean. If the height of the waves of the subterranean fluid be greater than the elasticity of the solid shell which confines them can bear, that shell must be fractured to a greater or less extent, and through the openings thus produced in it, the internal matter, in a state of igneous fusion, may issue, producing volcanic phenomena. Or in fine, the fracture may be only external, in which case the consequences will be limited to local derangement and disturbance of the surface.

Let us first consider the case in which an undulation is propagated to the surface without fracture.

12. The part of the surface of the earth thus affected, and all bodies placed upon it, suffer in this case the same sort of disturbance and dislocation as does a ship floating on water upon which a system of waves is formed. The waves have a progressive motion in some certain direction, passing successively under the ship, which is alternately raised to the crest and lowered to the hollow of each successive wave as it passes. Neither the water nor the ship partakes of this progressive motion. If they did no alternate rise and fall would take place; the ship once placed on the crest of a wave would be carried forward by the water on which it floats, and would still remain on the crest of the same wave, a circumstance which never takes place. In the same manner exactly the undulations imparted to the surface of the earth by the fluid confined within it, have a certain progressive motion which causes every part of the surface over which they pass, alternately to rise and fall, through a height equal to the difference of the levels of the crest and hollow of the wave.

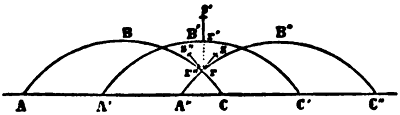
13. But besides this, another effect of much importance is produced upon solid structures, which are placed, as buildings are, in a position perpendicular to the level surface of the ground. That surface when it is affected by the wave, ceases to be level. As the wave passes it, it is first inclined in one direction, and after being raised to the summit of the wave it is inclined in the opposite direction. Any solid structure, having a vertical position, would, therefore, while the wave passes, be inclined from the vertical, first to the right, and then to the left, according as it is successively at one side or other of the wave.

Such superficial undulation of the ground, would therefore produce a twofold displacement of all such objects; first an alternate motion upwards and downwards in the vertical direction, and secondly, a sort of rocking or oscillating motion like that of a pendulum, leaning alternately right and left of its true vertical position.

This will be better understood by reference to fig. 2, in which

three successive positions of the wave are represented by A B C, A′ B′ C′, and A″ B″ C″. A building or other object in a position perpendicular to the ground is represented at *r s* on the slope of the wave where it leans from the vertical to the right. When the wave has advanced to the position A′ B′ C′, the foot of the building

Fig. 2.



is raised to the crest of the wave at *r′*, and the building, *r′ s′*, is then vertical, having in the interval been gradually raised from its inclined direction. When the wave has progressed to A″ B″ C″, the foot of the building has been again lowered to its first position, but being now on the slope, A″ B″, it will be inclined to the left of the vertical, as represented at *r″ s″*.

14. Thus by the undulations passing successively under it, such a building will be alternately raised and lowered through a certain vertical height, and at the same time *rocked* right and left through a certain angle of vibration.

The undulations which produce earthquakes are sometimes rectilinear and propagated in parallel lines and in a single direction. In other cases they form concentric circles, and are propagated from a certain central point, like the waves produced on the surface of still water round the point at which a pebble is dropped into it.

The angle through which objects will be deflected from the perpendicular in the rocking motion imparted to them, will depend on the angle of the slope of the wave, and the latter will depend on the proportion which the height of the undulation bears to its amplitude. The less the height, and the greater the amplitude, the less will be the deflection from the perpendicular. In the cases of many earthquakes, this deflection is so small, that the cohesion of the materials of building is generally sufficient to prevent them from falling notwithstanding their deflection.

That a building may stand, though inclined considerably from the perpendicular, is proved by examples which occur in almost every city. The leaning towers of Pisa and Bologna have stood for seven hundred years.

The effect of the alternate motion, upwards and downwards in the vertical direction, must depend more upon the rapidity of the alternation than upon the range of the elevation and depression. *It is* easily conceivable that the ground may be *slowly* raised and

depressed through a very considerable height or depth, without producing any superficial derangement, but if such elevation and depression take place with much rapidity, great disturbance must ensue.

15. Humboldt, who has been personal witness of a considerable number of these phenomena, and has elaborately investigated the recorded effects of the most remarkable of them, says that the undulations are propagated chiefly in parallel lines, and with a progressive velocity of from twenty to thirty miles per minute. He observes that the cases in which the waves issue from a centre of undulation, and are propagated in circles around it, are more rare, and that when it takes place, the height of the waves diminish as their distance from the common centre increases.

In general, the undulations are inconsiderable in their vertical height and velocity of oscillation, so that in places affected by them, the strength of buildings is sufficient to resist their effects, and we constantly hear of slight shocks of earthquakes being sensible, which are attended with no injurious consequences. Bells are sometimes thus rung, and furniture and other loose objects more or less displaced without other more serious consequences.

16. The vertical shock however, in places more subject to these visitations, is sometimes attended with far more grave effects. In the case of the earthquake, by which the town of Riobamba, at the foot of Chimborazo, was destroyed in 1797, the bodies of many of the inhabitants were hurled to a height of several hundred feet, and thrown upon the hill of La Cullca, beyond the small river Lican.

17. Humboldt cites examples of the circular propagation of terrestrial undulations at the Holy Sea, or Lake Baikal, in Siberia (between lat. 51° and 55°, and long. 103° and 110° E.), and in the Celestial Mountains, or Thian-schan, in Chinese Turkestan, (between lat. 42° and 43°, and long. 80° and 90° E.) The intermediate region is subject to the double influence of the circular undulations propagated from these two centres, and Humboldt ingeniously explains the freedom from earthquakes of a certain intermediate tract between two such centres of undulation, by the principle of interference which plays so important a part in optics and acoustics. He supposes that along such a tract the crests of the waves of one system coincide with the hollows of those of the other, so that the ground being just as much elevated by the one as it is depressed by the other, remains undisturbed, while the country at either side is agitated, and perhaps devastated, by the shocks.

18. In certain cases, the motion imparted to the surface is not merely that of undulation properly so called, which, as already

explained, can only produce vertical and oscillating motions, it has been found, in some cases, that the ground has been affected by an horizontal as well as vertical displacement. In some cases also a gyratory movement of the ground has been observed, so that after the shock, the direction of the walls of buildings, and the relative bearings of fixed objects, such as buildings, trees, and the directions of hills and valleys have been changed.

19. Humboldt states, that although the undulations of the surface of the ground, which take place in earthquakes, have been ascertained with some degree of precision, their periods of alternation have not been so well observed. In the city of Quito, which stands at the foot of the volcano of Rucu-Pichincha, at an elevation of nearly 10000 feet above the level of the sea, he often felt strong shocks of an earthquake at night. Yet the buildings of the city, including many lofty churches, fine cupolas, and houses consisting of many stories, were very rarely injured by them, although much slighter shocks damaged lower buildings on the Peruvian plains.

The natives of the country, who are accustomed to the phenomena, many hundred earthquakes occurring during a single generation, explain this difference by the greater or less rapidity of the horizontal oscillation, which, according to their experience, is far more destructive than the vertical or rocking motion produced by regular undulation.

20. The earthquakes which produce a gyratory motion of the ground are the most destructive, and happily also the most rare. After the earthquake which destroyed Riobamba in 1797, and that which took place in Calabria in 1783, walls were changed in their direction without being thrown down, rows of trees, which were previously strait and parallel, were, after the shock, in different directions, and even in curved rows. Fields were changed in their relative positions, those in which two different crops were growing having interchanged places.

21. Humboldt was shown among the ruins of Riobamba a place where the entire furniture and contents of a certain house were found buried under the remains of another. Numerous cases occurred in which heavy articles of furniture were transported several hundred yards from their original position, so that questions of ownership were raised and brought before the courts of justice.

In this case the ground, rent in various places, was affected at once by vertical and horizontal oscillations, so that while one part was heaved upwards another adjacent to it was sunk downwards and transferred horizontally under the former. Such tossing and agitation of the surface presents a striking resemblance to the

irregular and tumultuous agitation of the surface of the sea after a storm, and must arise from such a condition prevailing for the moment in the igneous ocean upon which the solid crust of the earth rests.

22. A popular impression prevails that earthquakes are preceded by peculiar atmospheric phenomena, such as a profound stillness of the air, a suffocating and oppressive heat, and a misty horizon. Exact and extensive observations made in various countries, and for long periods of time, have proved that this is without any foundation in fact. Humboldt states not only as the result of his own experience, but as that of those who have lived for many years in regions where earthquakes are frequent, that they take place indifferently in all weathers and in all states of the atmosphere. He experienced them himself in clear and fair as well as in rainy weather, and as often in a fresh east wind, or in a storm, as in a calm. He observed no disturbance or exceptional condition in the magnetic needle, the barometer or thermometer, either on their approach or during their continuance. His own observations within the tropics, and those of Adolphe Erman during the earthquake of the 8th of March, 1829, at Irkutsk, near Lake Baikal, lat. 53°, were in this respect in complete accordance.

Nevertheless, the subterranean convulsion appears to have been in some cases attended with atmospheric effects, which would indicate some connection between the phenomena and the electric state of the surface and of the atmosphere. Thus, for example, during the long-continued trembling of the ground in the Piedmontese valleys of Pelis and Clusson, considerable variations of the electric tension of the atmosphere were observed, which could not have arisen from any storm, the sky being at the time quite serene and unclouded.

23. From some statistical results, it would seem that there are grounds for supposing a connection between the prevalence of earthquakes and the season of the year. Numerical data, collected with much care, by MM. de Hoff, Merian, and Hoffmann, indicate the greatest frequency of these phenomena at the epochs of the equinoxes.

24. It is a fact not unworthy of remark, that notwithstanding the backward state of physical science generally among the ancients, and their total ignorance of the modern science of geology, the true physical cause of earthquakes was indicated in unequivocal terms by Pliny,* who denominated them "Subterranean storms;" and Seneca† gave the germ of all that was known about their causes until a very recent date.

* *Pliny, ii., 79.* † Nat. Quæst, vi., 4—31.

25. Earthquakes are often attended, though not at all, as is commonly supposed, preceded by awful subterranean sounds. These noises, however, appear to have no relation whatever to the violence of the shock. Some of the most tremendous of these convulsions have, on the contrary, been unaccompanied by any noise whatever. This was the case with the great earthquake of Riobamba already mentioned, one of the most terrible catastrophes of its class which has been recorded in the physical history of the globe.

The noises which are heard most commonly occur after the shock, and seldom at the place where the earthquake has the greatest violence. In the case of the earthquake of which Tacunga and Hambato were the centre and points of greatest action, no noise was heard at these places, but violent subterraneous detonations were heard at Quito, which is fifty-five miles, and at Ibarra, about one hundred miles distant from those points, at twenty minutes after the shock.

The subterranean thunder, if it may be so called, is sometimes heard at places situate beyond the limits of the shocks. Thus in the case of the violent earthquake which occurred at Lima and Callao, on 28th October, 1746, a noise resembling a clap of subterranean thunder was heard at Truxillo, where no shock whatever was felt, nor even the least trembling of the ground.

Sometimes the subterranean thunder is heard after the shocks have ceased. The great earthquake which occurred on 16th November, 1827, in New Grenada, and was described by Boussingault is an example of this. Some time after the cessation of the shocks, subterranean detonations were heard at regular intervals of half a minute along the whole Cauca valley.

26. The character of the noise attending earthquakes has differed greatly in different cases. Sometimes it has been a rolling sound like that of thunder, or the discharges of cannon in rapid succession. Sometimes it is described as resembling the clanking of chains. At Quito it is often sudden, like a near thunder-clap, and sometimes it is clear and ringing like the clashing of glass, as if enormous masses of vitrified matter were shattered in subterranean caverns.

27. Owing to the fact that solid bodies are good conductors of sound, the sonorous undulations being propagated through them with a velocity ten or twelve times greater than through the atmosphere, the subterranean noise developed in these convulsions may be heard at great distances from the seat of the agency which produces it. During a violent eruption of the volcano of St. Vincent, one of the smaller West India Islands, and while a prodigious torrent of lava issued from it, a loud noise resembling

thunder unaccompanied by any trembling of the ground, was heard at the distance of 632 miles to the south-west of the crater on the plains of Calaboso, and on the banks of the river Apure, one of the tributaries of the Orinoco. This noise was audible over an area of nearly 50000 square miles. So far as distance is concerned, this was as if a noise attending an irruption of Vesuvius were heard at London.

28. During the great eruption of Cotopaxi, one of the most lofty peaks of the Andes, subterranean sounds like discharges of artillery were heard at Honda, on the Magdalena river. This is the more remarkable, inasmuch as the crater of Cotopaxi is not only 18000 feet above the level of Honda, and the distance measured in a direct line between the two points is 463 miles, but vast mountain masses such as Quito, Pasto, and Popayan, as well as innumerable valleys and ravines are interposed between them. The sound was therefore evidently in this case propagated through the solid crust of the earth from a great depth, and not through the air.

Another striking example of the propagation of sound from the depths of the earth to great distances through its crust was presented in the case of the violent earthquake which occurred in New Grenada, in 1835. On that occasion, subterranean thunder was heard at Popayan, Bogota, Santa Martha, and Caraccas, and also in Hayti, in Jamaica, and on the shores of Lake Nicaragua. At Caraccas the thunder continued without any sensible trembling of the ground for seven hours.

It would appear that in some cases the solid telluric shell is strong enough to resist the undulations of the subterranean igneous fluid while it transmits the sonorous vibrations. It is difficult to convey an adequate idea of the impression which these terrible sounds, issuing from the depths of the earth, produce, when they are not attended by any dynamical or other phenomena. It is as if a preternatural voice coming from below addressed the entire population. The listener waits after each roll of the sound in an agony of suspense for what may follow.

29. One of the most remarkable examples of these subterraneous sounds unaccompanied by any disturbance of the surface of the ground, was that which occurred in the great mining regions of Mexico, in 1784, and which is known in that country as the *Bramidos subterraneos* (subterraneous roaring) of Guanaxuato.*

* Humboldt, Essai Polit. sur la Nouv. Esp., vol. i., p. 303. Cosmos, Trans. vol. i., p. 196, and note 187.

Guanaxuato is the capital town of the mining district of that name, situate in the Sierra de Santa Rosa, at 160 miles north-west of Mexico, and at an elevation of 6000 feet above the level of the sea. It is irregularly built on mountain declivities, and is surrounded by deep shafts, through which the produce of the rich gold and silver mines is brought to the surface. More than an hundred of these shafts are sunk within a radius of fifteen miles round the town. There is no active volcano in the neighbourhood.

The subterranean sounds were first heard at midnight on the 9th January, 1784, and they continued without intermission for more than a month. A circumstantial description of the progress of the phenomenon was obtained by Humboldt on the spot, from the reports of numerous witnesses, and from the documents of the municipality, which he was allowed to copy.

From the 13th to the 16th it seemed as if a rolling thunder alternately with loud and sharp thunder-claps issued from storm clouds beneath the foundation of the town. These sounds, which increased from the beginning by slow degrees, until they attained their greatest loudness and violence, ceased by the same slow degrees. It was remarked, however, that the range of the phenomena was not considerable, the sounds being heard only in the mountainous part of the Sierra, from the Cuesta de los Aquilares to the north of Santa Rosa. No sounds were heard in a basaltic district at a few miles distance, nor in the detached portions of the Sierra, twenty-four to twenty-eight miles north-west of Guanaxuato. Not only was the surface of the ground free from the least trembling or other movement, but none was felt in the workings of the mines, which passed in all directions at great depths below the surface.

30. When this extraordinary phenomenon commenced, the inhabitants of the place were seized with uncontrollable terror, and with a spontaneous movement began to take flight. This was at first resisted by measures of extraordinary severity on the part of the authorities. Flight from the city was punished with a fine of 1000 piastres, or two months imprisonment, and the militia were ordered to arrest and bring back the fugitives. One of the most curious circumstances attending the commencement of the disturbance was a proclamation issued by the magistracy, declaring "that in their wisdom they would be well aware of the approach of real danger, and that whenever it might arise they would give notice to the inhabitants to fly, but that as yet it would be sufficient to continue the processions," meaning no doubt some religious ceremonies.

The inhabitants of the surrounding table lands being prevented

by their fright from bringing supplies into the markets of the town, a famine commenced, and the power of the authorities being at length overborne, a general flight ensued. Nearly the whole population deserted the town, in which large masses of the precious metals, the produce of the surrounding mines, had been stored. Bands of plunderers lingered to seize this treasure. After a while the inhabitants being familiarised with the continuance of the subterraneous thunder, unaccompanied by any other symptoms of earthquake, the more courageous returned to the town and fought with the robbers in defence of their property.

In no part of the mountainous regions of Mexico was anything of this kind ever before known or heard of, nor has it ever recurred since. Thus it would-appear, that as chasms in the inferior parts of the crust of the earth are opened or closed, the sound produced by the agitation of the igneous ocean, which roars beneath it, is propagated or intercepted in different directions and at different times.

31. It would be a great mistake to assume that earthquakes are always merely local phenomena of very limited range. On the contrary, they have in some cases been manifested over a large portion of the surface of the globe. The great earthquake by which Lisbon was destroyed on the 1st November, 1755, was felt over the whole extent of Europe, from the Alps to the coast of Sweden, over Northern Germany and the shores of the Baltic, across the Atlantic to the West Indies, where the shocks were sensible in the islands of Barbadoes, Martinique, and Antigua, and across the continent of North America to the great northern lakes.

Distant fountains were interrupted in their flow. Thus the hot springs of Töplitz were first dried up but soon reappeared, sending up unusual quantities of water of an ochreous colour.*

32. That the solid surface of the bottom of the ocean shared in the general undulation manifested over so great an extent of the continents on this occasion could not be doubted, if no other evidence of it existed save the transmission of the undulation across the Atlantic. But we have more direct evidence of this in the sudden changes of elevation of the water of the ocean itself. At Cadiz the sea rose above sixty feet, and in the islands of Barbadoes, Martinique, and Antigua, where the normal rise of the tide does not much exceed two feet, the water suddenly rose

* The fact that earthquakes had the effect of interrupting the flow of springs was known to the ancients, and is noticed by Demetrius of Calatia.

twenty feet, and was moreover discoloured, having the blackness of ink.

33. During the earthquake the water retired from the harbour at Lisbon, leaving the bar uncovered and dry, but it soon returned, rushing in enormous volumes, so as to rise in some places to the height of sixty feet. The shores were everywhere inundated, and the seaport of St. Eubal's, about twenty miles south of Lisbon, was submerged and totally disappeared.

The records of these convulsions of the earth supply many examples showing that the bottom of the sea has shared the perturbations of the land. In the case of the great earthquake which desolated Peru, in 1746, the Pacific rushed upon the coast with irresistible fury, destroyed several seaports, carrying the vessels which floated in them to great distances up the country, and submerging a large tract of land near Callao, so as to convert it into a permanent bay.

VIEW OF NAPLES AND VESUVIUS.

EARTHQUAKES AND VOLCANOES.

CHAPTER II.

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rises.—51. Also certain gases—Artesian fire-wells.—52. Carbonic acid—its effects in former states of the globe—origin of coal beds.—53. And marbles.—54. Mud volcanoes.—55. Those of remote origin.—56. Progressive development.—57. Formation of dome-shaped mountains.—58. Crater of elevation.—59. Active volcanoes.—60. Successive stages of their formation.—61. Not uniformly or permanently active.—62. Intervals of activity and repose.—63. Dependent on the height.—64. Stromboli.—65. Guacamayo.—66. Volcanoes of the Andes.—67. Exceptions explained.—68. Eruptions often lateral.—69. Groups of small cones.—70. Remarkable spectacle of Cotopaxi.—71. View of an active crater.—72. Remarkable permanence of the form of craters.—73. Effects of snow-capped cones.—74. Cause of the fiery appearance of ejected matter.—75. Islands of volcanic origin.—76. Volcanic theories.

34. A REMARKABLE submarine earthquake occurred in the Gulf of Mexico in 1780, during which a mass of water was carried against the western coast of the island of Jamaica, which in an instant submerged the entire town of Savannah la Mar. Not a building nor living thing escaped this prodigious irruption of water.

The same island underwent still more extensive devastation from an earthquake which occurred there in 1692. Three-fourths of Port Royal, the capital of the island at that time, suddenly sunk down, and with all its inhabitants was submerged by the sea. Large warehouses which stood upon the quays were submerged to such a depth, that their roofs were from 20 to 40 feet below the surface of the water. The subsidence was so evenly vertical and so free from any lateral displacement or rocking motion, that many of the houses sunk without falling; so that after the catastrophe the chimney-tops of some of them were seen, as well as the topmasts of ships wrecked in the harbour, projecting from the surface of the water. A vessel of war which had been under repair in one of the docks was transported over several of the submerged buildings, and finally rested upon one of the sunken houses, breaking through the roof.

In the first shock of this earthquake a tract of the adjacent country of the extent of above a thousand acres was instantaneously submerged.

35. It has been calculated that in the great earthquake of Lisbon, a portion of the earth's surface more than four times the area of Europe was affected by the undulation, without taking into account any part of the submarine disturbances which attended it.

36. As examples of shocks and tremblings of the ground which have continued from hour to hour for several successive months, Humboldt produces the following examples, all of which took place at great distances from any active volcano. On the eastern slope

of Mount Cenis, at Fenestrelles and Pignerol, the phenomena commenced in April, 1808. The liquid contained in full glasses exhibited a constant agitation and trembling. In the United States, at New Madrid, and Little Prairie, north of Cincinnati, the trembling commenced in December, 1811, and continued through the winter of 1812. In the Pachalik of Aleppo the shocks continued during the months of August and September, 1822.

37. Since the perturbation of the crust of the earth is produced by the agitation of the subjacent igneous ocean, it is no otherwise dependent on the nature of the matter which forms that crust than so far as such matter may be more or less susceptible of receiving and transmitting the undulations. Accordingly we find earthquakes occurring in every sort of soil, and strata from the loose alluvial soil of Holland to superficial strata of granite.

38. It is, however, certain that the mechanical structure of certain strata are such as to arrest the undulation. Thus, when an earthquake shock, or wave as we shall call it, is propagated along a line of coast, or along the foot of a mountain chain, certain points of interruption have been observed, over which the wave passes without producing any disturbance, resuming its character beyond their limits. Such tracts are well known, and have preserved their immunity from the shocks which affect the country at either side of them for centuries. It appears that the undulation of the subterranean fluid passes under these without affecting them. The Peruvians, who are of all people the most familiar with earthquakes, call these tracts *bridges*.

39. It does not at all follow, however, that because the superficial strata are not affected by the undulation, the inferior strata are exempt from it. At the beginning of the present century earthquake shocks were felt with such violence in the workings of the deep silver mines of Marienberg, in Saxony, that the miners took flight in alarm, and ascended by the shafts to the surface, where, nevertheless, they found that no shocks or trembling had been felt.

40. On the other hand, the superficial strata are sometimes affected by undulations, from which inferior strata are exempt, as is proved by what took place at Fahlun and Persberg, a mining district of Sweden, in November, 1823, during a violent shock of an earthquake, which spread terror among the inhabitants, while the miners employed in the deep workings experienced no disturbance whatever.

41. The undulations of earthquakes proceed so often in directions parallel to mountain chains, that it might be conjectured that they are directed by some influence exerted by the wall

the fissures of the strata, between which the matter forming the chain was originally forced up. Many exceptions, however, to this are presented by earthquakes which have been propagated in directions transverse to those of the mountain chains. Thus, in South America they have crossed the littoral chain of Venezuela and the Sierra Parime. In Asia they have been propagated in January, 1832, from Lahore and the foot of the Himalaya, across the chain of the Hindoo Coosh as far as Badakschan on the Upper Oxus, and even to Bokhara.

42. We shall conclude this brief notice of these terrible terrestrial perturbations by the general reflections upon them made by Humboldt, who himself witnessed so many, and who has more than any other observer of nature studied and investigated them.

"In conclusion," says he, "I would advert to the cause of the deep and peculiar impression produced on the mind by the first earthquake we experience, even if it is unaccompanied by subterranean noise. I do not think that this impression is produced by the recollection at the moment of the dreadful images of destruction which historic relations of past catastrophes have presented to our imaginations: it is rather occasioned by the circumstance that our innate confidence in the immobility of the ground beneath us is at once shaken. From our earliest childhood we are accustomed to contrast the mobility of water with the immobility of the earth: all the evidences of our senses have confirmed this belief; and when suddenly the ground itself shakes beneath us, a natural force of which we have had no previous experience presents itself as a strange and mysterious agency. A single instant annihilates the illusion of our whole previous life; we feel the imagined repose of nature vanish, and that we are ourselves transported into the realm of unknown destructive forces. Every sound affects us —our attention is strained to catch even the faintest movement of the air—we no longer trust the ground beneath our feet. Even in animals similar inquietude and distress are produced; dogs and swine are particularly affected, and the crocodiles of the Orinoco, which at all other times are as dumb as our little lizards, leave the agitated bed of the river, and run with loud cries into the forest.

"To man the earthquake conveys a sense of danger of which he knows not the extent or the limit. The eruption of the volcano, the flowing stream of lava threatening his habitation can be fled from; but in the earthquake, turn where he will, danger and destruction are around him and beneath his feet. Though such emotions are deeply seated, they are not of long duration. The inhabitants of countries where long series of weak shocks succeed each other, lose almost every trace of fear. On the coasts of Peru,

where rain scarcely ever falls, and where hail, lightning, and thunder are unknown, these atmospheric explosions are replaced by the subterranean thunder which accompanies the trembling of the earth. From long habit and a prevalent opinion that dangerous shocks are only to be apprehended two or three times in a century, slight oscillations of the ground scarcely excite so much attention in Lima as a hail-storm does in the temperate zone."

43. Although we are in the habit of congratulating ourselves, in this country, for our exemption from the terrible visitations of convulsions of the ground, it is certain that beneath the floor upon which our dwellings are established, there exists a seat of disturbance of a certain force and constancy. This is abundantly proved by the fact, that not less than 256 or 257 slight earthquake-shocks have been recorded, of which 139 took place in Scotland. Yorkshire, Derbyshire, Wales, and the south coast of England, have been the principal theatres of the remainder.

44. In the cases of convulsions which have been noticed in the preceding chapter, the effects of the phenomena have been generally limited to derangement more or less violent of the surface. When the internal forces acting outwards are exercised with greater energy, or when the external strata of the earth's crust exercise less resistance, disruptions take place, and through the openings thus produced the internal matter is ejected. The physical character of the matter thus thrown out, and the state in which it is found at the moment of its ejection, depend in a great degree upon the depth of the strata from which it has proceeded.

Of all the substances thus thrown out through the external crust from the interior of the earth, the most frequent is water. That liquid appears to be deposited in terrestrial strata, having depths more or less considerable, and it necessarily acquires the temperature of the strata in which it is thus confined. In ordinary springs rising from inconsiderable depths within the limits of the superficial strata, the temperature in warm seasons is generally lower considerably than that of the air at the surface, and hence arises the coolness of common spring-water. But when water rises from depths much more considerable, lying below the stratum of invariable temperature,* it is found to have a higher temperature than the air.

45. It was first observed by Arago, that water rising in Artesian wells had a temperature greater and greater as the depth of the well augmented. This observation involved a physical principle of high importance, supplying, as it did, a thermal index to the depth of hot springs.

* See Tract on Terrestrial Heat.

46. It has been shown in our tract on Terrestrial Heat, that in descending below the stratum of invariable temperature, the temperature of the strata increases at the rate of about 1° for every 50 feet. The stratum of invariable temperature, at the mean latitudes, being at a depth of less than 100 feet, and its temperature being nearly the same as the mean temperature at the surface; we may state in round numbers, that if the temperature at the surface be taken to be 50°, the temperature at the depth of one mile will be 150°, at the depth of two miles will be 250°, and at the depth of three miles will be 350°. Now, water at the temperature of 250° produces steam bearing a pressure of 30 lbs. per square inch, being about half that of the steam generated in a common locomotive, while water at 350° produces steam having a pressure of 130 lbs. per square inch, being more than twice the pressure in a locomotive.

47. The natural hot springs which exist in various parts of the globe must issue from strata whose depth corresponds to their temperature, rising through fissures or perforations in the superior strata, produced by disruptions effected by the pressure from within prevailing over the tenacity of the materials composing such strata. If the temperature of the water issuing from such springs could be taken to be that which it had in the reservoir from which it has risen, such temperature would supply at least an approximate index of the depth of such reservoir. But it must be considered, that in rising to the surface it passes through a succession of strata of constantly decreasing temperature, composed of materials of various conducting powers and capacities for heat, and that in its ascent it must part with more or less of its heat, and therefore that its temperature on issuing from the spring at the surface must be less than that of the subterranean reservoir from which it has risen. How much must, in each case, be allowed for this loss of temperature is a problem of considerable difficulty, and one which at best, with our present data, admits of no more than a rough approximative solution.

48. Observations made very extensively upon thermal springs, prove them to be completely independent of the strata from and under which they rise. Neither do they prevail exclusively in volcanic regions. Indeed, Humboldt affirms that the hottest permanent springs hitherto discovered are some found by himself, at a great distance from any volcano, as for example, the "Aguas Calientes de las Trincheras," between Puerto Cabello and New Valencia, in Venezuela, South America, the temperature of which was 194½°, and which issued through a stratum of granite; and the "Aguas Comangillas," near Guanaxuato, in Mexico, of which the temperature was 205½°, being only 6½° below the boiling point.

According to what has been explained of the law of temperature in relation to depth, the reservoirs from which these springs rise must be at a depth of nearly two miles.

It is remarked that springs of such moderate temperatures as from 120° to 160° are very constant, not only in their thermal state, but also in their chemical composition, while the hotter springs are subject to considerable variation. Thus, the thermal springs within these limits which have been known and observed in Europe, have never undergone the slightest change, either in their temperature or in their chemical analysis, since exact physical observations have been made upon them, which comprises at present an interval of about sixty years. While the hotter springs contain in solution the smallest proportions of mineral matter, they are found to be subject to a variation of temperature not inconsiderable. Thus, the springs of Las Trincheras above-mentioned, which, when observed by Humboldt in 1800, had a temperature of 194½°, were found by Boussingault, in 1823, to have a temperature of 206½°, having thus increased in temperature 12° in 23 years.

49. Nothing is more remarkable and curious respecting springs, whatever be their temperature, than the secular permanency which attends so many of them. The fountains of Greece still flow in the same places as they did when described by the historians, and sung by the poets, of the classic age. The river Erasinos, which rose in lake Stymphalus, after flowing a certain distance disappeared in the earth, but sprung up again out of the declivity of the mountain Chaon, two hours' journey south of Argos. This spring, which is mentioned by Herodotus, still issues from the same point in the slope of the mountain. In the centre of the temple of Apollo, at Delphi, was a small opening in the ground from which, from time to time, an intoxicating vapour was said to proceed, and which was supposed to proceed from the adjacent well of Cassotis. Over this chasm the priestess Pythia took her seat whenever the oracle was to be consulted, and the words she uttered after inhaling the mephitic vapour were believed to be the revelations of the god.

Of this chasm no trace remains, but the well of Cassotis still exists, and is known as that of St. Nicholas. Its waters still pass under the site of the temple of Apollo.

Of the other classic fountains which still flow may be mentioned that of Castalia at the foot of Mount Parnassus, Piréné at Corinth, the thermal springs of Ædepsus on the coast of Eubœa near Chalcis. It is remarkable that in a tract of country so peculiarly subject to frequent and violent earthquakes, the strata in the main continue to preserve their relative position, so that even those narrow holes and fissures, through which those subterranean waters

force themselves up, have remained unchanged during the long interval of 2000 years.

As further examples of this permanency, Humboldt adduces the example of a natural jet d'eau at Lillers, near Calais, which was bored in 1126, and now, after a lapse of seven centuries, still supplies the same quantity of water, which issues with the same force.

50. If the reservoir from which water rises be at such a depth that its temperature greatly exceeds the boiling point, the water will be converted into vapour the moment it escapes from the place of its confinement, just as was the case with the water shut up in the generators of the steam apparatus projected by Perkins. In that case, the steam will issue from the crevice of the earth exactly as it would from the safety-valve of a high-pressure steam-engine.

51. The vapour of water is not however by any means the only elastic fluid which forces its way to the surface from the interior of the globe. Various gases are also ejected in enormous quantities. The gas called carburetted hydrogen, which, evolved by artificial processes, is now so universally used for the purposes of illumination, issues in vast quantities from the interior of the earth through fissures of greater or less magnitude, and thus presented by Nature herself, has actually been used for illumination in China for more than ten centuries back. The artesian FIRE-WELLS of China, at Ho-tsing are well-known. The gas has from very ancient times been collected in tubes of bamboo, and being thus rendered portable, has been used for illumination in the city of Khiung-tscheu.*

52. But of all the gaseous ejections from the interior, the most frequent and abundant is carbonic acid. It is certain that at earlier epochs in the history of our globe, thousands of centuries before the appearance of man and of the other tribes of animals that now inhabit it, when the fissures and crevices supplying free communication between the surface and the interior were far more numerous and capacious than they are at present, and when the temperature of the solid crust was much higher, this gas, mixed with hot steam, issued from the interior in quantities infinitely greater than at present, so as to give totally different qualities to the atmosphere. These qualities, owing to the large proportion of carbonic acid, and the great quantity of aqueous vapour always suspended in the air, were eminently favourable to the production of a vegetation exuberant to a degree of which there is now no existing parallel. Hence arose those vast forests and other large collections of vegetable matter, which, being fossilised in succeeding

* Humboldt, "Central Asia," tom ii. 519—530.

revolutions of the globe, have supplied those inexhaustible stores of mineral fuel which have, through the application of science, become mechanical agents of infinite power, as well as sources of artificial light and heat.

53. These prodigious volumes of carbonic acid also supplied other purposes in the terrestrial economy at that early period. Entering into combination with lime, which also prevailed in abundance, lime-stone rocks of every kind, including those beautiful marbles which have become so important a material in the industrial and ornamental arts, were produced; for these rocks, as is well known, are nothing but carbonates of lime, the carbonic acid constituting nearly half of their entire mass.

54. The transition from the ejection of gases and liquids to that of molten rocks exhibited in the effects of volcanoes, is marked by the intermediate phenomena of the ejection of hot mud. According to Humboldt, although SALSES or mud volcanoes in their normal state present little to arrest attention, their origin is characterised by the imposing phenomena of earthquakes, subterranean thunder, the upswelling of vast tracts of country, and the ejection of lofty jets of flame. A recent and well-observed example of such a phenomenon is presented in the case of the mud volcano of Jokmali, on the peninsula of Apscheron, east of Baku on the shores of the Caspian sea. This peninsula has always been the theatre of singular subterranean phenomena, and flames have so frequently, in past times, issued from the ground upon it, that it has been regarded with veneration by the oriental fire-worshippers. On this peninsula on the 27th November, 1827, flames blazed up from the ground to so great a height that they were seen at the distance of 24 miles, in which state they continued for three hours, after which they decreased to the height of three feet. They issued from a crater which was formed by their ejection, and continued to burn in that way for 20 hours. This ended in the ejection of enormous fragments of rock, and quantities of hot mud.

55. Of mud volcanoes of more remote origin we have examples in the case of the Monte Zibio, near Sassuolo in the Duchy of Modena, and the salse near Girgenti, in Sicily. Fragments of rocks like those ejected by Jokmali may be seen around the former. The salse has continued in the secondary state of activity for fifteen hundred years, descriptions of it at that early epoch having come down to us. It consists of several cone-shaped mounds, varying in height from eight to thirty feet, and subject to constant change, not only in height but in shape. Small craters are formed at the summit of the cones, which contained more or less water, and from which gas from time to time is disengaged.

The mud which is ejected from these volcanoes is cold. In a similar mud volcano mentioned by Humboldt, at Damak, in the province of Samarang, in the island of Java, the mud ejected has a high temperature.

The gaseous eruptions from these salses are usually attended by noise, and consist of different sorts of gas, sometimes hydrogen, sometimes carbonic acid, and occasionally nitrogen. The hydrogen is often mixed with naphtha.

56. After the first imposing phenomena such as those above described in the case of Jokmali have ceased, the mud volcanoes in general seem to be the result of a feeble activity of the interior forces of the globe obstructed in their effects by some impediments in the fissures or openings by which communication with the surface is obtained. The coldness of the mud seems to prove that the seat of the force is not at any great depth.

57. From the examples of subterranean activity presented by superficial convulsions, earthquakes, thermal springs, and jets of gas and steam, we pass to the formation of volcanoes properly so called. The internal forces, acting with unequal effect on different parts of the solid crust of the earth, surmount its resistance at points where it has least tenacity, and upheaving the incumbent strata, raise them into dome-shaped masses, like those of the Puy de Dome and Chimborazo, without, however, producing actual fracture. Sometimes the mass thus upheaved gives way at the summit of the dome, which separates so as to leave a circular cavity of a certain depth surrounded by a nearly perpendicular wall, having on the exterior a gradual slope, which formed the declivity of the dome before the disruption.

58. The roundish cavity thus formed is called a "crater of elevation."

59. If the energy of the subterranean forces be sufficiently intense, the floor of this crater will be disrupted, holes and fissures will be formed in it, communicating with the liquid fire which fills the solid shell of the earth, steam and acid gases will be ejected in vast quantities, followed by ignited scoriæ, and red hot stones, and fragments of rock, after which will follow torrents of that incandescent earthy matter in a state of pasty fusion, which has been called LAVA; in a word, an active VOLCANO will be formed.

60. Now there are here several distinct stages, at any one of which the phenomena may be brought to a close, according to the relation between the energy of the upheaving force and the local tenacity of the earth's solid crust. If the upheaving force do not *much* exceed that tenacity it may spend its entire energy in *producing* swelling of the surface of the ground more or less pro-

nounced. If the excess be greater still, a dome-shaped hill or mountain will be produced. A greater excess again will cause the disruption of this dome, and its conversion into a crater of elevation. Finally, if the internal force be sufficient to break a way through the entire mass of solid strata which forms the shell of the earth, the fiery fluid central matter, rising through the opening thus made for it, will issue from the holes, crevices, and fissures in the floor of the crater, and overflowing or breaking a way through the surrounding wall, rush in a torrent of fire down the slopes of the dome-shaped hill thus formed.

61. The volcano thus formed is never uniformly active. The eruptions are only occasional. When an internal wave or tide of the fiery central ocean passes the base of the opening, a pressure is produced by which the molten matter is forced up and ejected in the form of lava. In its ordinary state, however, when no eruption takes place, volumes of smoke more or less dense usually rise from the fissures, and upon looking down into them, the luminous incandescence of their walls and of the matter they include is visible. The light of this illuminating the smoke and ashes, which rise over the crater, often give to them a lurid light which appears like, and is sometimes mistaken for flame.

62. The intervals of activity and repose of volcanoes are often of very long duration. Thus in the case of Vesuvius, the eruptions were renewed with unabated force after an interruption of several centuries. In the time of Nero, Etna was considered as approaching to entire extinction, and according to Ælian, the summit of the mountain at a later period was gradually sinking, so that it could no longer be seen as a landmark by vessels at sea from the same distances.

63. Humboldt affirms that it may be considered as a pretty well established law of volcanoes that those which have least elevation are characterised by the most unceasing activity. He proves this law by many examples, and explains it by the supposition that a less internal force is sufficient to raise the molten masses to low than to high summits. He gives the following series of elevations of the craters of remarkable volcanoes:—

	Feet.
Stromboli	2318
Guacamayo	2500
Vesuvius	3876
Etna	10,870
Peak of Teneriffe	12,175
Cotopaxi	19,070

64. Now of these, Stromboli has been in a state of activity from the Homeric age to the present, so unceasing that it has served

and still serves all the purposes of a stupendous light-house to ships navigating that part of the Mediterranean. The entire island situate off the north coast of Sicily is of volcanic formation.

65. The activity of Guacamayo, situate in the province of Quiros, at about 88 miles from Chillo, near Quito, is so continuous that detonations are heard daily from it, even at the distance of Chillo. On the other hand, the eruptions of Vesuvius are comparatively rare, and those of Etna still more so, while those of the lofty volcanic peaks of the Andes are separated by intervals of little less than a century.

66. As a further evidence of the prevalence of this volcanic law may be mentioned the cases in which volcanoes do not rise, like Etna and Vesuvius, from the midst of extensive plains, but have their bases established on table-lands of great elevation, in which cases it is observed, that even in the most terrible eruptions no lava properly so called is ejected, the matter thrown up being merely ignited scoriæ. Yet the violence of the subterranean commotion is rendered manifest by the terrible detonations which are heard at distances of four hundred miles. Examples of this are presented in the volcano of Popayan, South America, the base of which is 6000 feet above the level of the sea, that of Pasto upon the table-land of the Andes at an elevation of 8500 feet, and those of the Andes near Quito.

67. Wherever exceptions to this volcanic law have been presented, Humboldt considers them as only apparent, and that they may be explained by the casual obstruction of the fissures of communication between the seat of the volcanic force and the surface.

68. The volcanic eruptions do not necessarily proceed from the crater. Indeed, in some volcanoes, eruptions from the crater are much less frequent than those which proceed from other parts of the mountain; as, for example, from the sides where the solid walls of the internal fissure often present less resistance. Lateral fissures and openings are in such cases produced, over which "cones of eruption," as they are called, are formed. In this case, a series, or row of cones, are formed at certain distances along the line of fissure, from each of which the eruption takes place, all the intermediate part of the fissure being immediately closed up.

69. The internal forces also often break out at numerous points, distributed over a large space, forming a number of smaller cones which are described as having the form of bells or beehives. The cones produced by the eruption of Vesuvius in *October*, 1822, offer an example of these, as do also the Hornitos *de Jorullo*, observed by Humboldt, and delineated by him in his

"Vues des Cordillères," pl. XLIII., p. 239. Other examples are presented by the small cones of the volcano of Awatscha, and of the field of lava in Kamtschatka, described by Erman.

70. Around each mouth from which the fiery matter is projected, a cone of cinders and ashes is formed by the return of the matter which has been projected upwards. These cones vary greatly in height and magnitude, and appear to have no relation to the general elevation of the mountain, the smaller class of volcanoes often producing the highest cones. One of the most remarkable of these cones is that of the Volcano of Cotopaxi, in the eastern Cordillera of the Andes, about 34 miles S.S.E. of Quito. The general form of this remarkable mountain is that of an immense cone, shaped with an accuracy almost geometrical. The summit is about 19000 feet above the level of the sea, and nearly 10000 above the adjacent table-land. The snow line is at 4400 feet below the summit. The cone, therefore, above this line is coated with perpetual snow, except at the times of eruptions, in which the solid sides of the cone becoming incandescent, the snow suddenly melts, and descending in torrents down the flanks of the mountain, leaves the conical summit uncovered. "Of all the volcanoes which I have seen," says Humboldt, "in either hemisphere, the cone-formed Cotopaxi is at once the most regular and the most picturesque. Before each great eruption, the sudden fusion of the snow, which habitually invests its vast cone, announces the coming catastrophe. Even before the appearance of smoke issuing from its lofty crater, the sides of the cone acquire a glowing temperature, and the mass of the mountain assumes an aspect of most awful and portentous blackness."

71. It is difficult to imagine any spectacle more awfully grand than the view of a crater in activity presented to an observer stationed at the summit of the surrounding wall. The space beneath him appears like the surface of agitated half-molten matter contained in a colossal cauldron. The surface swells and intumesces; from the cracks and fissures vapours issue; small chasms here and there alternately open and close, showing within them red hot molten matter; burning fragments are from time to time thrown up, and fall back upon the sides of the mounds surrounding the mouths from which they have been vomited; each small eruption of this kind is regularly preceded and announced by small earthquake shocks, which sensibly shake the ground beneath the feet of the observer; occasionally lava issues in a fiery torrent from these fissures and mouths, but not in sufficient quantity to break through the walls of the crater, but sometimes the flow of this red hot pasty matter is so abundant

that it breaks the wall, and rushes down the side of the mountain.

72. It might be inferred from the occurrence of such tremendous phenomena, that the form and condition of volcanic craters would be subject to constant and considerable change. Their variation is, nevertheless, much less than might naturally be expected. Thus, for example, the ramparts of the crater of Vesuvius were accurately measured by Saussure in 1773, and again by Humboldt and Lord Minto in 1822-3. In that interval of 50 years no considerable variation took place.

73. The case of Cotopaxi producing torrents of water mixed with scoriæ and enormous blocks of ice precipitated down the slopes of the mountain by the sudden fusion of the snow which crowns its summit, is not singular. The same phenomena attend all the volcanoes whose cones rise above the line of perpetual snow, of which the chain of the Andes presents many examples. Independently of these occasional inundations of the external surface, these volcanoes exert a constant action even during their apparent repose, by the slower fusion of the snow in immediate contact with them, and the infiltration of the water through the crevices and fissures of the rocks of which they are formed. Subterranean reservoirs of water are thus formed at and below their bases, with which the streams and rivulets of the surface communicate. It has been ascertained that in these dark reservoirs fish multiply more largely than in the open waters, and that when the caverns containing such waters are suddenly opened, as they sometimes are, by the earthquakes which always precede violent eruptions, water, fish, and tufaceous mud are thrown out in one confused mass. Humboldt says, that when on the night of the 19th June, 1698, the summit of the Carguairazo, at the height of nearly 20000 feet above the level of the sea, suddenly fell in, leaving two stupendous peaks of rock as the sole vestiges of the rampart of the crater, masses of tufa, in a liquid state, and of clayey mud, containing immense numbers of dead fish, were spread over a tract of about fifty square miles in extent, rendering the whole space barren.

In some cases, the quantities of this dead fish which have been ejected have produced putrid fevers, fatal to a large part of the population.

74. The fiery appearance which is so often observed over the volcanic craters in great eruptions is not flame, as it is commonly supposed to be. It is due principally, if not altogether, to the reflection of the lurid light which issues from the crater, by which the clouds, vapour, ashes, and other ejected matter, forming the column over it, are illuminated, but in part, also, from scoriæ and

dust ejected in a state of incandescence. There is, strictly speaking, no combustion in or over the crater, and therefore the term burning mountain is physically incorrect.

75. The production of volcanoes, or of volcanic craters, which remain passive, as above explained, is by no means confined to those parts of the solid crust of the earth which lie above the waters of the ocean. The bottoms of seas, and even of lakes, are subject to such convulsions still more frequently than the land. When the bottom of the sea is thus up-heaved, islands are produced, the form, character, and magnitude of which depend on that of the up-heaved mass. The form of Palma, one of the Canaries, and the peaks which it throws up to the height of 7000 feet, and that of Nisyrus in the Ægean, present examples of this. The volcanic origin of the latter was known to the ancients, which gave rise to the fable that Neptune, when pursuing Polybotes, one of the giants that fought against the gods, followed him across the sea as far as this land of Cos, where having torn off a part of the island, he hurled it upon him, and buried him under it. This fragment of Cos was called Nisyrus.

When the dome up-heaved from the bottom of the sea breaks at the summit, so as to form a crater of elevation, a part of the annular rampart is sometimes destroyed, so that the sea enters, and an enclosed bay is formed, where innumerable tribes of coral animals build their cellular dwellings.

It happens also frequently that the craters of elevation on land become filled with water, so as to form lakes surrounded by a rampart.

76. Various theories have been proposed to explain the phenomena of volcanoes, and to solve the questions, What is it that burns? What excites such prodigious degrees and quantities of heat? heat sufficient to fuse not only the metals, but the most refractory earths, imparting to masses of fused earth a heat which many years are required to dissipate. We have throughout these pages assumed, that the origin of all these phenomena is the fluid incandescent matter contained within the solid crust of the earth, such being, after much discussion, the explanation now generally accepted by geologists. Among the hypotheses which have been proposed, and which received and merited much consideration, though now put aside, was the chemical theory of Sir Humphry Davy, in which the evolution of heat and light in the depths of the volcanic craters, was ascribed to the chemical action of the most oxydable metals, such as potassium, sodium, calcium, &c. It is a fact, familiar to all that have studied the elements of chemistry, that a piece of potassium immersed in water will instantly become decomposed, combining with its

oxygen and liberating the hydrogen. If the existence of the metals in their simple state in the lower strata of the earth be admitted, any accession of water to them would immediately produce this sort of combustion.

Our limits, and the object of this tract, preclude us from entering upon this question here beyond this mere indication of the ingenious hypothesis of the illustrious chemist; and as the theory proposed has been generally abandoned, such a discussion is the less necessary.

To illustrate the generally received theory, we have here subjoined an hypothetical section of the crust of the earth, showing the progress upwards of the igneous fluid from the internal liquid fire, FF, to the mouth of the crater at C.

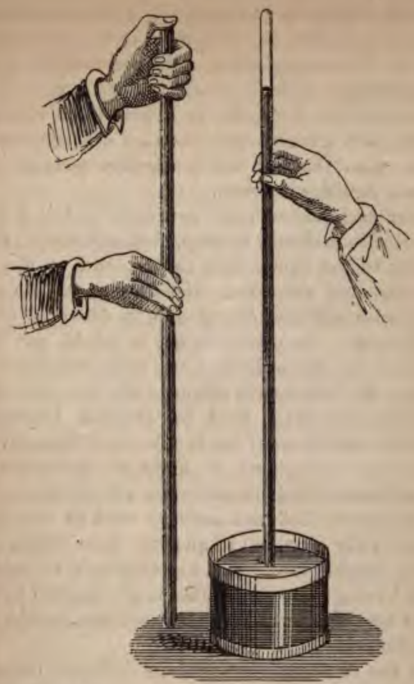


Fig. 1.—PROCESS OF MAKING A BAROMETER.

THE BAROMETER.

. Origin of the name.—2. Conditions necessary to render the instrument useful.—3. To purify the mercury.—4. To cleanse the tube.—5. To fill the tube.—6. To invert it in the cistern.—7. Construction of a barometer.—8. Effect of temperature on the barometric column.—9. To ascertain if the vacuum above the column be perfect.—10. Expedients to render minute variations of altitude visible.—11. Diagonal barometer.—12. Wheel barometer.—13. Common siphon barometer. —14. Use of the barometer to measure heights.—15. Density of strata affected by their temperature.—16. Fall of barometer in the balloon ascent of Gay Lussac.—17. Extreme variations of the barometric column in a given place.—18. Its diurnal variation.—19. How it may prognosticate the weather.—20. Fallacy of popular rules.—21. Barometric prognostics.

1. THE manner in which a column of mercury, suspended in a glass tube, is balanced by, and measures the weight of, the atmosphere, has been explained in a former number of this series. Such an apparatus, properly mounted and supplied with the accessories which are necessary to indicate the changes of the altitude of the mercurial column, is called a barometer, from two Greek words, βαρος (*baros*), which signifies weight, and μετρον (*metron*), which signifies measure.

2. To render such instruments generally useful, it is necessary that their indications should be in perfect accordance, that is, that being brought to the same place they should at the same time always have the same altitudes. If this were not the case, observations made with different barometers in different places would not be comparable. In other words, it would not follow that the pressures of the atmosphere in two different places are really different when the barometric columns are unequal, inasmuch as such inequality may arise from an original difference in the materials and construction of the instruments themselves.

To render the indications of different barometers identical several precautions in their construction are necessary.

3. It is necessary that the mercury used in the instruments should be absolutely identical in quality, since otherwise columns having equal heights would not necessarily have equal weights, and columns having unequal heights might happen to have equal weights. In fine, the weights of two columns would not be proportional to their heights.

To render the mercury contained in different barometers perfectly identical, the first requisite is that it be perfectly pure and free from admixture with any other substance. To attain this object is not quite so easy as may at first appear. It frequently happens that small particles of solid impurities, such as dust and dirt, are mixed with mercury; so much so, that they may be seen upon its surface, often forming a sort of scum. To separate these from it, the mercury is enclosed in a bag of chamois leather, and squeezed there until it passes through the pores of the leather. By this process the chief part of the solid impurities are extricated, since they will not pass through the pores of the leather, and are therefore *strained* from the mercury.

Aqueous, and other liquid matter, is also sometimes mixed with the mercury. These are disengaged by boiling it. All such liquid matter is evaporated at a temperature much lower than that at which mercury boils, and they are consequently expelled in the form of vapour long before the mercury reaches its boiling temperature.

4. When the mercury has been thus purified, it is next

necessary to render the tube perfectly clean on its inner surface. It generally happens that tubes exposed to the air, always more or less damp, have a film of moisture upon them. It is necessary therefore to expel this. After cleaning the tube by internal friction, it is warmed over the flame of a spirit lamp from end to end, so as to evaporate any moisture which may remain upon it and render it perfectly dry.

5. Mercury is then poured into it by means of a funnel with a very small aperture, until a column of about ten inches has entered. However pure this mercury may be, and however clean the tube, it will be more or less mixed with air, which will enter with it as it passes from the funnel. To dismiss this air the tube with the mercury in it is heated over a spirit lamp, until it is raised to a temperature higher than that of boiling water. By this process the air combined with the mercury, or adhering to the inner surface of the tube, being expanded by the heat, escapes from the tube, as well as any moisture that may have entered with the mercury.

Mercury is again introduced in the same manner, and again heated, and the process is repeated until the tube has been completely filled.

In this process it is usual to heat the mercury to nearly the same temperature as that of the tube before pouring it in, since otherwise there would be some danger of cracking the tube, by the expansion or contraction of the glass consequent on the sudden change of temperature.

6. When the tube is in this manner completely filled, the open end is finally stopped with the finger, and being inverted it is plunged in a small cistern of mercury (fig. 1, p. 177). When the finger under the mercury in the cistern is withdrawn, the column in the tube will subside until it falls to the altitude which will be balanced by the atmospheric pressure.

If several tubes be prepared in this manner, it will be found that the columns of mercury sustained in them at the same time will be exactly equal.

7. In adapting such an apparatus to indicate minute changes in the pressure of the atmosphere, there are several provisions to be made.

The height to be measured being that of the surface of the column in the tube above the surface of the mercury in the cistern, it is not enough to ascertain the position of the surface in the tube, unless the surface in the cistern have a fixed level. Now it is evident, that whenever the surface in the tube rises, the surface in the cistern must fall, and *vice versâ*, inasmuch as whatever mercury enters the tube must leave the cistern, and

whatever flows from the tube must return to the cistern. If the magnitude of the surface in the cistern be very considerable compared with the bore of the tube, and if extreme accuracy be not necessary, the effects arising from this cause will be too minute to need any correction; but if that extreme accuracy is desired, which is necessary in barometers used for philosophical experiments, then means must be provided for keeping the mercury in the cistern at a fixed level, or for measuring the change of level.

Fig. 2.

In fig. 2, the cistern A B is represented as having an index at P, showing the point at which the level of the mercury in the cistern should stand. A screw is represented at V, by turning which the bottom can be elevated or depressed, so that when the level in the cistern falls it may be raised, or when it rises it may be lowered, and thus the level may always be adjusted so as to correspond with the point of the index. The scale represented at D E is divided with reference to the level determined by the point of the index P.

8. In most of the uses to which the barometer is applied the variations in the altitude of the mercurial column are very minute, so minute indeed that the most refined and delicate expedients are necessary in the observation and measurement of them. It is a fact familiar to every one, that all bodies, and more especially fluids, expand and contract by changes of temperature. Mercury, like others, expands when its temperature is raised, and contracts when it is lowered. Now when it expands it becomes bulk for bulk lighter, and when it contracts it becomes bulk for bulk heavier. It follows, therefore, that the barometric column, even when its altitude is the same at different times, will have different weights, the weight being less when the temperature is higher, and greater when the temperature is lower.

The dilatation and contraction of mercury has been ascertained to amount to the 9990th part of its entire volume for each degree of temperature by which it is raised or lowered, and a column of 30 inches would therefore suffer a change of the 333rd part of an inch for each degree of temperature.

The extreme variations of temperature in this climate between summer and winter being about 50°, the barometric columns which indicate equal pressures at the two extreme temperatures, would differ in height by about the sixth or seventh part of an inch.

When barometric observations made in different places are

to be compared one with another, it is therefore necessary to allow for the difference of temperature, and this is usually done by calculating at both places what the height of the column would be if the temperature were that of melting ice, or 32°.

9. It is of extreme importance in the use of barometers to be always sure that no portion however small, of air or other elastic fluid, is contained in that part of the tube which is above the summit of the mercurial column, for if any such fluid be there, it will react upon the mercurial column and will depress it, so that its altitude, instead of expressing the pressure of the atmosphere, will express that pressure diminished by the pressure of the air or other elastic fluid which is above the column in the tube.

Now it happens that nothing is more easy than to ascertain whether any such fluid is there. It is only necessary suddenly to incline the tube from the vertical position, so as to cause the mercury to be forced up to the top by the atmospheric pressure, in consequence of the *vertical* height of the column being rendered less than that which balances the weight of the atmosphere. If in such case the mercury striking the top of the tube renders the blow audible by a distinct, sharp, and well-defined sound, it may be concluded that the top of the tube is free from air, for if air be present, even in the smallest quantity, it will react like a cushion or *buffer*, so as to soften the blow of the mercury, and deprive the sound of that sharp and distinct quality.

10. The changes of altitude incidental to the barometric column are so minute that various expedients have been resorted to, to render them more easily and accurately observable.

More sensible indications would be obtained by adopting a barometer of a lighter fluid than mercury. Thus, water is $13\frac{1}{2}$ times lighter than mercury, and, consequently, a water barometer would exhibit a column $13\frac{1}{2}$ times greater than that of mercury.

Such a column would, therefore, measure about 34 feet, and a change which would produce a variation of about the tenth of an inch in the column of mercury, would produce a variation of an inch and a third in the column of water.

But to the use of water, or any other liquid save mercury, for barometric purposes, there are numerous and insuperable practical objections. Independently of the unwieldy height of the column, which would render it impossible to transport the barometer from place to place, all the lighter liquids would produce vapour in the upper part of the tube, which would vitiate the vacuum, would react against the barometric column, and disturb its indications. The consequence of this has been, that

mercury has been invariably retained as the only practicable fluid for barometers.

Several expedients, however, have been adopted in barometers used for common domestic purposes to render their indications more sensible. Although these are inapplicable in barometers used for scientific purposes, yet, as they are frequently adopted in domestic barometers, it may be useful here to notice them.

11. A form of barometer, called the diagonal barometer, is represented in fig. 3. In this the upper end of the tube is bent, so that the scale, instead of being limited to the length C D, is extended over the greater length C B.

Fig. 3.

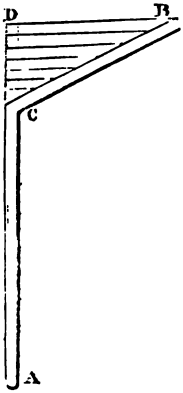
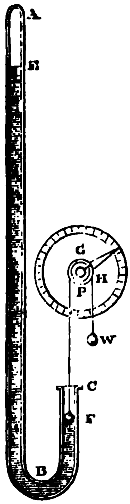


Fig. 4.



12. A form of barometer, called the wheel barometer, is represented in fig. 4. In this, the tube, instead of having a cistern, is continued of the same diameter, having its lower end bent upwards at B C. A float is placed upon the mercury at F, which rises and falls with it. The change of altitude of the level F corresponds with that of E, and the difference between the two levels E and F is the height of the barometric column. The changes of this height are always double the change of level of the surface E F. The float F is connected by a string with a wheel, H, which carries an index that plays upon a graduated dial plate, G. In this manner the magnitude of the graduated scale may be made to bear any proportion, however great, to the change of level of the mercury at E, so that the smallest change of the barometric column will produce a considerable motion of the index.

13. One of the most common forms of this instrument is represented in fig. 5. The lower part of the tube being bent into the form of a siphon, like the wheel barometer, is inserted in the lower part of an iron stop-cock, the upper part of which is *inserted* in a small globular cistern containing the mercury. When the stop-cock is open the column in the tube is subject

to the pressure of the atmosphere acting on the mercury in the cistern. If the tube be inclined so that the mercury will fill the top of it, and the stop-cock be then closed, the instrument may be transported from place to place without risk of air entering the tube, or other derangement. The diameter of the globular cistern bears so great a proportion to that of the tube, that a rise or fall of the mercury in the tube, within the usual limits of barometric variation, produces a very inconsiderable variation in the level of the mercury in the cistern, or if greater accuracy be desired, the scale attached to the tube may be so divided as to measure, not the actual variation of the level of the column in the tube, but its variations relatively to that of the mercury in the cistern. Thus, if the diameter of the cistern be four times the diameter of the tube, the area of its section will be sixteen times that of the tube, and when the level of the mercury in the tube falls through an inch, the level of the mercury in the cistern rises through the sixteenth of an inch, so that the real decrease of the mercurial column is only fifteen sixteenths of an inch. It is evident that, if it be desired, the scale may be so divided that an actual fall of an inch may be marked as one-sixteenth less than an inch, and so of other variations.

Fig. 5.

In barometers for domestic use this extreme precision is not necessary, and is so much the less so, as the most important indications of the barometer are those which depend on the *variation* of the height of the column, and not on its absolute height.

14. It has been shown, that when a barometer is carried upwards in the atmosphere, the column of mercury in the tube falls, because the force which sustains it is diminished by an amount equal to the weight of the column which it leaves below it. By comparing, therefore, the height of the column in the barometer at any two stations, one of which is above the other, we can ascertain directly the weight of a column of atmosphere extending from the lower to the higher station. Thus, for example, if the column of mercury in the barometer at the lower station be 30 inches, and at the higher station 20 inches, it follows that a column of air whose base is at the lower station, and whose summit is at the higher station, will have a weight equal to that of a column of mercury 10 inches high, and there-

fore that the quantity of air composing such a column will be one-third of the quantity composing a column extending from the lower station to the summit of the atmosphere.

If the atmosphere were uniformly dense, the barometer would supply a most easy and simple means of determining its actual height.

In the example just given, the column of air between the two stations would weigh one-third of the weight of a column extending from the lower station to the summit of the atmosphere; and, if the air were uniformly dense, it would follow, therefore, that the entire height of the atmosphere would be just three times the height of the upper above the lower station. But, owing to the circumstances already explained, which produce a gradual rarefaction of the air as the height increases, it follows that the heights of columns of air are not proportional to their weights.

If the only cause which produces a gradual rarefaction of the air as we ascend in the atmosphere were that which has been just stated, namely, the weight of the incumbent air, it would not be difficult to find a rule by which a change of altitude might be inferred from observing the change of pressure indicated by a barometer. Such a rule has been determined, and is capable of being expressed in the language of mathematics, although it be not of a nature to be rendered intelligible in an elementary and popular treatise.

15. But there are other causes affecting the relation of the change of pressure to the change of altitude. The density of any stratum of air is not alone affected by the incumbent pressure of the superior strata, but also by its own temperature. If any cause increase this temperature, the stratum will become more rarefied, and with a less density will support the same incumbent pressure; and if, on the contrary, any cause produce a fall of temperature, it will require a greater density with the same pressure. In the one case, therefore, a change of elevation which would be necessary to produce a given change in the height of the barometer would be greater than that computed on theoretical principles; and in the other case it would be less. The temperature therefore forms an essential condition in the calculation of heights by the barometer.

Formulæ have been contrived, partly by theoretical principles, and partly from observation, by which the difference of height of two stations may be deduced from the observations simultaneously made at them on the barometer and the thermometer. To apply such a rule it is necessary to know, first, the latitude of the place of observation; secondly, the heights of the barometer and thermometer at each of the two stations, besides some other physical

data, to comprehend which it would be necessary to have reference to some principles drawn from the physics of heat and from physical astronomy, which cannot be introduced here. Such a formula, therefore, cannot be usefully given here.

16. The barometer in the balloon in which the celebrated De Luc made his scientific voyage, fell at the greatest altitude to 12 inches. Supposing the barometer at the surface to have stood at that time at 30 inches, it follows from this, that he must have left below him in quantity exactly three-fifths of the entire atmosphere, since 12 inches would be only two-fifths of the complete column sustained in the barometric tube. His elevation at this moment was estimated to have been 20000 feet; but it is certain that he had not attained a point amounting to more than a small fraction of the entire altitude of the atmosphere.

Since the density of air is proportional to its pressure, other things being the same, it would follow that the density of the air in which the balloon floated on this occasion was only four-tenths of the density at the surface.

Now when the barometer is at 30 inches, air is 10400 times lighter than mercury; and, consequently, the air surrounding De Luc's balloon must have been 26000 times lighter, bulk for bulk, than mercury. The height, therefore, of air above the balloon, supposing its density to be undiminished in rising, would have been 26000 feet, and in this case the entire height of the atmosphere would be nearly 50000 feet. But here it is to be considered, as in the former case, that in rising above the level of the balloon, the air would constantly diminish in density; and, consequently, a column supporting 12 inches of mercury would have a much greater elevation than 26000 feet.

17. The physical effect of which the barometric column is the measure, is the weight of the atmosphere at the place where this barometric column is situated; and consequently, the variations, whatever they may be, which are incidental to the column, indicate corresponding variations in the weight of the atmosphere. Now it has been found that the barometric column is subject to two species of variation: one of an extremely minute amount, and which takes place at regular periods; the other of much greater amount, and which may be considered as comparatively contingent and accidental. The extreme limit of this latter variation is, however, not great. The greatest height, for example, which the barometer kept at the Paris Observatory has been known to attain is 30·7 inches, and the lowest 28·2 inches, the difference being 2·5 inches, or $\frac{1}{12}$th of the average height of the column.

The mean height of the barometer at Paris, obtained from

observations continued for several years, has been found to be 29·77 inches.

18. The periodical variations of the barometric column are extremely complicated, though very minute. In winter, it is found that the column attains a maximum height at nine in the morning; it falls from this hour until three in the afternoon; it then begins to rise, and attains another maximum at nine in the evening. In summer, the hour of the first maximum is eight in the morning, and that of the minimum four in the afternoon; that of the second maximum being eleven at night. In spring and autumn, this maximum and minimum take place at intermediate hours.

19. The accidental variations of the barometer, or, to speak more properly, those which are not periodic, and which are much greater in magnitude, have been generally supposed to be prognostics of change in the weather, and hence the barometer is sometimes called a weather-glass. Rules have been attempted to be established by which from the absolute height of the mercurial column the coming state of the weather may be predicted; and we accordingly find the words, Rain, Fair, Changeable, &c., engraved upon the scale attached to common domestic barometers, as if, when the mercury stands at the heights marked respectively by these words, the weather is always subject to the vicissitudes expressed by them.

It requires but little reflection on what has been stated to show the fallacy of such indications. The absolute height of the mercurial column varies with the position of the instrument. A barometer in Fleet Street will be higher at the same moment than one on the top of St. Paul's, and consequently two such barometers would indicate different coming changes of the weather, though absolutely situate in the same place. Two barometers, one of which is placed at the level of the Thames, and the other at the top of Hampstead Hill, will differ by half an inch, and, consequently, would indicate, according to the usual scales, different coming changes.

20. It is evident, therefore, that the absolute height of the barometer cannot in itself be an indication of anything but the weight of the atmosphere in the place where the instrument stands, and the words engraved on barometric plates, which have been just referred to, are altogether unworthy of serious attention.

Nevertheless, at a given place the column varies between certain limits, usually from $2\frac{1}{4}$ to $2\frac{1}{2}$ inches, and when the mercury is at its highest limit, the prevailing character of the weather is fair, when at its lowest it is rainy and stormy, while at the intermediate altitude it is variable.

21. Different meteorological observers have attempted to embody and generalise the results of their observations in a collection of rules, by which the weather may be prognosticated. The following brief general maxims have been proposed :—

1. Generally the rising of the mercury indicates the approach of fair weather, the falling of it shows the approach of foul weather.

2. In sultry weather, the fall of the mercury indicates coming thunder. In winter the rise of the mercury indicates frost. In frost, its fall indicates thaw, and its rise indicates snow.

3. Whatever change of weather suddenly follows a change in the barometer, may be expected to last but a short time. Thus, if fair weather follow immediately the rise of the mercury, there will be very little of it; and, in the same way, if foul weather follow the fall of the mercury, it will last but a short time.

4. If fair weather continue for several days, during which the mercury continually falls, a long succession of foul weather will probably ensue; and again, if foul weather continue for several days while the mercury continually rises, a long succession of fair weather will probably succeed.

5. A fluctuating and unsettled state in the mercurial column indicates changeable weather.

Here is another set of weather barometric prognostics :—

1. If the barometer begin to fall slowly and steadily after a long continuance of dry weather, rain will certainly follow; but if the fair weather have been of very long duration, no perceptible change may take place for some days, and the longer the time which elapses between the fall of the barometer and the commencement of the rain, the longer will be the subsequent continuance of the foul weather.

2. The preceding rule may be inverted. If the barometer begin to rise slowly and steadily, after a long continuance of rainy weather, fair weather will certainly follow; and if several days elapse between the rise of the barometer and its commencement, it will have so much the longer continuance.

3. If, in either of these cases, the changes follow promptly upon the motion of the mercury, the new state of the weather will not be of long continuance.

4. If, during two or three days successively, the barometer rise slowly and steadily, rain nevertheless falling constantly, fair weather will certainly follow, and *vice versâ*. But if the barometer rise during rain, and then fall at the commencement of fair weather, the fair weather will be very transient; and *vice versâ*.

5. A sudden fall of the mercury in spring or autumn is followed by high winds; in summer, and especially during sultry weather, it is followed by a thunder-storm. In winter, a sudden fall after

long-continued frost, is followed by a change of wind, and a thaw and rain; but after a continued frost, a rise of the mercury is usually followed by snow.

6. No rapid fluctuations of the mercury are to be taken as indications of any change of long continuance. It is only the slow, steady, and continuous rise or fall, that is to be attended to as such a prognostic.

7. A rise of the mercury late in the autumn, after a long continuance of wet and windy weather, generally indicates a change of wind towards the north, and approaching frost.

THE SAFETY LAMP.

1. Introductory observations.—2. Fire-damp—Sir Humphry Davy invents the Safety Lamp.—3. Nature and laws of flame investigated and discovered by him, and rendered subservient to his invention.

1. Art often presses into its service the discoveries of science, but it sometimes provokes them. Art surveys the fruit of the toil of the philosopher, and selects such as suit her purposes; but sometimes, not finding what meets her wants, she makes an appeal to science, whose votaries direct their researches accordingly towards the desired object, and rarely fail to attain it.

One of the most signal examples of the successful issue of such an appeal presents itself in the *safety-lamp*.

2. The same gas which is used for the purposes of illumination of our cities and towns (and which, as has been stated, is obtained from coals by the process of baking in close retorts), is often spontaneously developed in the seams of coal which form the mines, and collects in large quantities in the galleries and workings where the coal-miners are employed. When this gas is mingled with common air, in a certain definite proportion, the mixture becomes highly explosive, and frequently catastrophes, attended with frightful loss of life, occur in consequence in the mines. The prevalence of this evil became so great, that government called the attention of scientific men to the subject; and the late Sir Humphry Davy engaged in a series of experimental researches with a view to the discovery of some efficient protection for the miner, the result of which was the now celebrated safety-lamp.

3. Davy first directed his inquiries to the nature and properties of flame. What is flame? was a question which seems until then never to have been answered or even asked.

All known bodies, when heated to a certain intensity, become luminous. Thus iron, when its temperature is elevated, first gives a dull red light, which becomes more and more white as the temperature is increased, until at length it becomes as white as the sun. Davy showed that gaseous substances are not exempt from this law, and that flame is nothing more than *gas* rendered *white hot.*

He further showed that if the gas thus rendered white hot be cooled, it will cease to be luminous in the same manner, and from the same cause, as would be the case with a red hot poker plunged in water.

He showed that the gas which forms flame may be cooled by putting it in contact with any substance, such as metal, which is a good conductor.

Thus, if a piece of wire net-work, with meshes sufficiently close, be held over the flame of a lamp or candle, it will be found that the flame will not pass through the meshes. The wire will become red hot, but no flame will appear above it.

It is not, in this case, that the gas which forms the flame does not pass through the meshes of the wire, but in doing so, it gives up so much of its heat to the metal, that when it escapes from the meshes above the wire, it is no longer hot enough to be luminous.

Sir Humphry Davy, in the researches which he was called to make discovered this important fact, which enabled him to explain the nature and properties of flame; and having so discovered it, he did not fail promptly to apply it to the solution of the practical problem with which he had to grapple.

This problem was, to enable the miner to walk, lamp in hand, through an atmosphere of highly explosive gas, without the possibility of producing explosion. It was as though he were required to thrust a blazing torch through a mass of gunpowder, without either extinguishing the flambeau or igniting the powder; with this difference, however, that the gaseous atmosphere to which the miner was often exposed was infinitely more explosive than gunpowder.

The instrument by which he accomplished this was as remarkable for its simplicity as for its perfect efficiency. A common lantern, containing a lamp or candle, instead of being as usual enclosed by glass or horn, was enclosed by wire gauze of that degree of fineness in its meshes which experiment had proved to be impervious to flame. When such a lantern was carried into an atmosphere of explosive gas, the external atmosphere would enter freely through the wire gauze, and would burn quietly within the lantern; but the meshes which thus permitted the cold gas to

enter, forbade the white-hot gas within to escape without parting with so much of its heat in the transit as to deprive it of the character and properties of flame; so that, although it passed into the external explosive atmosphere, it was no longer in a condition to inflame it.

The lamp thus serves a double purpose: it is at once a *protection* and a *warning*. It protects, because the flame within cannot ignite the gas outside the lantern. It warns, because the miner, seeing the gas burning within the lantern, is informed that he is enveloped by an explosive atmosphere, and takes measures accordingly to ventilate the gallery, and meanwhile to prevent unguarded lights from entering it.

Nothing can be imagined more triumphantly successful than this investigation of Sir Humphry Davy. Some philosophers have the good fortune to arrive at great scientific discoveries in the prosecution of those inquiries to which the course of their labours leads them. Some are so happy as to make inventions of high importance in the arts, when such applications are suggested by the laws which govern the phenomena that have arisen in their experimental researches. But we cannot remember any other instance in which an object of research being proposed to an experimental philosopher, foreign to his habitual inquiries, having no associations with those trains of thought in which his mind has been previously involved, he has prosecuted the inquiry so as to arrive not only at the development of a natural law of the highest order, the fruitful parent of innumerable consequences of great general importance in physics, but at the same time, to realise an invention of such immense utility as to form an epoch in the history of art, and to become the means of saving countless numbers of human lives.

WHITWORTH'S MICROMETRIC APPARATUS.

AMONG the many admirable machines produced by Mr. Joseph Whitworth at the Great Exhibition, was a micometric apparatus for establishing uniform standards of magnitude for taps, axles, and other important component parts of machines. By this instrument, magnitudes, so minute as even to elude the *microscope*, are submitted to mechanical measurement.

Two perfectly plane and smooth metallic surfaces are first

formed, partly by friction against each other, and partly by abrasion with a peculiar tool.

So plane are the surfaces of metal thus formed, that when one is laid upon the other no one part comes into closer contact than another, and there is included between them a stratum of particles of air which act like infinitely smooth rollers, and the surfaces move in contact one with another with a degree of freedom, owing to the lubricity of the air, which must be felt to be conceived. If, however, the surfaces be so severely pressed against each other as to exclude the air, the contact becomes so complete that it is with great difficulty they can be separated.

These surfaces, thus accurately formed, are used as standards to test other plane surfaces, and with these are tested the ends of a standard measure of metal, which is placed in an accurately formed horizontal metallic bed. One end bears against a metallic pin; another metallic pin, urged by a screw, presses against the other end; and if this metallic bar, by change of temperature or any other cause, suffer a change in its length amounting to the millionth part of an inch, that change is rendered perceptible by the following arrangement;—

The pin which bears against its extremity is moved by a screw, which has ten threads to the inch. On the head of this screw is a wheel, consisting of 400 teeth, which works in a worm driven by another wheel, the rim of which is divided into 250 visible parts. Now, since each thread of the original screw corresponds to the 1-10th part of an inch, each tooth of the wheel upon its head will correspond to the 4000th part of an inch, and each division of the wheel attached to the worm will correspond to the millionth part of an inch.

It is found, in the application of this apparatus, that a change in the position of the wheel attached to the worm, through one of the 250 divisions, is rendered sensible at the point of the screw which bears against the standard bar; but since the motion of the former wheel through one division can produce a motion amounting only to the millionth part of an inch in the point of the screw, this magnitude is thus rendered sensible.

To prove the accuracy of this micrometric apparatus, a standard yard measure made of a bar of steel, about three quarters of an inch square, having both the ends rendered perfectly true, was placed in it. One end of the bar was then placed in contact with the face of the machine, and at the other end, between it and the other face of the machine, was interposed a small flat piece of steel, termed by the experimenter "the contact piece," whose sides were also rendered perfectly true and parallel. Each division on the micrometer represented the one-

millionth part of an inch, and each time the micrometer was moved only one division forward, the experimenter raised the contact piece, allowing it to descend across the end of the bar by its own gravity only. This was repeated until the closer approximation of the surfaces prevented the contact piece from descending, when the measure was completed, and the number on the micrometer represented the dead length of the standard bar to the one-millionth part of an inch.

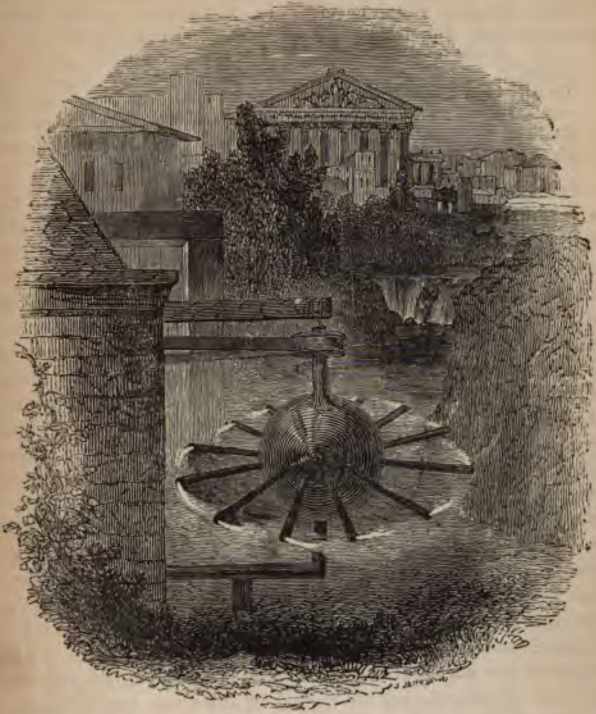
Eight repetitions of the experiment in a quarter of an hour produced identical results, there not being in any case a variation of one-millionth of an inch.

This method of operating was termed "the system of proof by the contact of perfectly true surfaces and gravity;" and in connexion with it was shown another interesting experiment.

When the micrometer was screwed up within one division of the number where contact would be presumed to occur, the warmth of the finger applied to the centre of the steel bar sufficed to expand and lengthen it instantaneously, so as to prevent the descent of the "contact piece."

The other method of proof was by having a small simple battery composed of a piece of zinc soldered on to a piece of copper and plunged into rain water, without the admixture of any acid; this was connected with the two ends of the measuring machine, and also with a delicate galvanometer. On pursuing the same process of advancing the micrometer one division at a time, no effect was produced until the last millionth of an inch of distance was traversed, and absolute contact occurred with the end of the bar, when the deflection of the needle of the galvanometer instantly betrayed the movement. Repeated experiments showed this to be unerring in the result, and on placing the finger on the middle of the bar, under the same circumstances as in the other course of experiments, the expansion was instantly detected by the deflection of the galvanometric bar.

By the application of this instrument, standard gauges for axles, taps, and other parts of machinery which it is desirable to maintain uniform, are constructed, and have been adopted by the Admiralty.



HERO OF ALEXANDRIA.

STEAM.

1. Power of steam manifested by natural evaporation. — 2. Early attempts at its mechanical application—Inventions of Watt.—3. Influence of steam power on mankind.—4. Its agency in commerce and the arts.—5. Analysis of its operation.—6. Combustion of coals.—7. Force developed by the evaporation of water.—8. Steam an invisible aeriform fluid.—9. Measure of the mechanical force developed.—10. Heat absorbed in evaporation.—11. Latent heat of steam.—12. Effect of varying pressure.—13. Mechanical force independent of the pressure.—14. Force developed by expansion.—

15. Force developed by condensation. — 16. Application of these three forces in steam engines.—17. Steam may act variously on piston.—18. Furnaces and boilers.—19. Evaporating power of fuel —20. Means of economising heat. — 21. Prevention of loss by radiation.—22. Inspection and reports of Cornish engines.—23. Greatly improved efficiency.—24. Actual mechanical virtue of coals. —25. Illustrations—Pyramids of Egypt.—26. Menai Bridge.—27. Railway engines.—28. Exhaustion of coal mines improbable.—29. Prospects of scientific discovery.

1. The surface of the globe has been inhabited by the human race for at least fifty or sixty centuries. During that long period their intelligence has been as acute, their interests as exigent, and their craving for material good, as insatiable as at present; yet a natural agent of vast power which existed around them, below them, and above them, whose play was incessant in the air, upon the earth, and in the waters under the earth, remained unobserved and undiscovered until the last century; its powers were imperfectly developed until late in the present century, and its still undeveloped consequences and effects, affecting the well-being and progress, physical, moral, and intellectual, of the whole human race, are such as the most acute and far-sighted cannot foresee. This giant power is Steam.

Since the day on which the land was divided from the waters by the Word of the Most High, evaporation,—that is the conversion of water into steam,—and condensation,—that is the reconversion of steam into water,—have been incessantly in operation upon a vast scale, and a corresponding amount of mechanical force has been developed and manifested on every part of the globe. By the solar heat, the waters of the ocean have been constantly vaporised and taken up into the higher regions of the air. Assuming there the form of clouds, they have been attracted by the mountains, and the more elevated parts of the land. There condensation has taken place, and the vapour has been re-converted into water, or even reduced by still greater cold to the solid state, and has been precipitated in the form of rain, hail, or snow, more or less, on all parts of the land, but chiefly, and most abundantly, on the summits of mountain chains, and on the more elevated regions. Descending from thence along the surface, they form the streams of rivers, and the torrents of cataracts, manifesting everywhere vast mechanical force, of which man has eagerly availed himself, without reflecting on its origin, or being conscious that he was using the indirect power of steam. By the force exhibited in the flow of rivers, transport from the interior of continents to their coasts has been effected since the earliest times, and among people the least advanced in the arts of life. By the force of cataracts, mills have been worked even in

ancient times and among rude nations. In a word, what is called WATER-POWER is, in reality, in all cases, the indirect power of steam, being due to the descent of that mass of liquid which had been previously elevated on so vast a scale by natural evaporation.

2. Nevertheless, these phenomena failed to suggest the artificial application of the same power. It was not until the commencement of the last century that any serious progress had been made towards the solution of that problem. About that time, engines were constructed, in which the elastic force of steam, as well as the force resulting from its re-conversion into water, was applied, as a mechanical power. The engines first constructed were defective, their performance unsatisfactory, and the cost of their maintenance greater than that of the power, which they aspired to supersede. At length, however, towards the middle of the last century, the genius of Watt was fortunately turned to this problem, and those great inventions were made, and improvements effected, the final result of which has been the creation of a power which has exercised a greater influence upon the condition of the human race, material, social, and intellectual, than was ever before recorded in the history of its progress.

3. To enumerate the benefits which the application of steam has conferred upon mankind, would be to count every comfort and every luxury we enjoy, whether physical or intellectual, many of which it has created, and all of which it has augmented in an immense proportion. It has penetrated the crust of the earth, and drawn from beneath it boundless treasures of mineral wealth, which, without its aid, would have remained inaccessible; it has drawn up, in measureless quantity the fuel on which its own life and activity depend; it has relieved men from many of their most slavish toils, and reduced their labour in a great degree to light and easy superintendence. It has increased the sum of human happiness, not only by calling new pleasures into existence, but by so cheapening former enjoyments as to render them attainable by those who before could never have hoped to share them: the surface of the land and the face of the waters are traversed with equal facility by its power; and by thus stimulating and facilitating the intercourse of nation with nation, and the commerce of people with people, it has knit together remote countries by bonds of amity not likely to be broken. Streams of knowledge and information are kept flowing between distant centres of population; those more advanced diffusing civilisation and improvement among those that are more backward. The press itself, to which mankind owes in so large a degree the rapidity of their improvement in

modern times, has had its power and influence increased in a manifold ratio by its union with the steam engine. It is thus that literature is cheapened, and, by being cheapened, diffused; it is thus that Reason has taken the place of Force, and the pen has superseded the sword; it is thus that war has almost ceased upon the earth, and that the differences which inevitably arise between civilised nations are for the most part adjusted by peaceful negotiation.

If this last result of a high state of civilisation and intelligence fails to be manifested, the case can only arise where a barbarous power intervenes, which is deaf to reason, and only controllable by brute force.

4. The steam-engine is a piece of mechanism by which fuel is rendered capable of executing any kind of labour. By it coals are made to spin, weave, dye, print, and dress silks, cottons, woollens, and other cloths; to make paper, and print books on it when made; to convert corn into flour; to press oil from the olive, and wine from the grape; to draw up metal from the bowels of the earth; to pound and smelt it, to melt and mould it; to forge it; to roll it, and to fashion it into every form that the most wayward caprice can desire. Do we traverse the deep?—they lend wings to the ship, and bid defiance to the natural opponents, the winds and the tides. Does the wind-bound ship desire to get out of port?—they throw their arms around her, and place her on the open sea. Do we traverse the land?—they are harnessed to our chariot, and we outstrip the flight of the swiftest bird, and equal in speed the fury of the tempest.

The substance by which these powers are rendered active is one which Nature has provided in boundless quantity in all parts of the earth, and though it has no price, its value is inestimable. This substance is WATER.

5. Those who desire to comprehend clearly and fully this vast agency, to which so much of the advancement and civilisation of mankind is due, must learn successively, 1st. The principles on which heat is evolved from fuel; 2nd. The expedients by which that heat is imparted to water; 3rd. The quantity of it which is absorbed in the conversion of water into steam; 4th. The mechanical power developed in this physical change; and 5th. The mechanism by which that power is applied to industrial uses.

It is obvious that the last of these points would include the exposition of the structure and operation of the varieties of steam-engines which have been applied to the purposes of commerce and manufactures, to railways and navigation. Upon this large subject it is not our present purpose to enter. We shall, however, explain the preceding, so as to enable our readers, with moderate

attention, to comprehend clearly the origin of the power of steam, and the physical conditions which determine its maintenance and its limits.

6. The general principles upon which heat is developed in the combustion of fuel have been already explained in our Tract on FIRE. It appears from what is there stated, that the varieties of coal are chiefly combinations of carbon and hydrogenous gases, the proportion varying in different sorts, but the carbon entering into its composition in very large proportions in all cases. In different sorts of mineral combustibles, the proportion of carbon varies from 75 to 90 per cent.

When carbon is heated to a temperature of about 700° in an atmosphere of pure oxygen, it will combine chemically with that gas, and the product will be the gas called *carbonic acid.* In this combination heat is evolved in very large quantities. This effect arises from the heat previously latent in the carbon and oxygen being rendered sensible in the process of combustion. The carbonic acid proceeding from the combustion is by such means raised to a very high temperature, and the carbon during the process acquires a heat so intense as to become luminous; no flame, however, is produced.

Hydrogen, heated to a temperature of about 1000°, in contact with oxygen, will combine with the latter, and a great evolution of heat will attend the process; the gases will be rendered luminous, and flame will be produced.*

If coals, therefore, or other fuel exposed to atmospheric air be raised to a sufficiently high temperature, their combustible constituents will combine with the oxygen of the atmospheric air, and all the phenomena of combustion will ensue. In order, however, that the combustion should be continued, and should be carried on with quickness and activity, it is necessary that the carbonic acid and other products should be removed from the combustible as they are produced, and fresh portions of atmospheric air brought into contact with it; otherwise the combustible would soon be surrounded by an atmosphere composed chiefly of carbonic acid to the exclusion of atmospheric air, and therefore of uncombined oxygen, and consequently the combustion would cease, and the fuel be extinguished. To maintain the combustion, therefore, a current of atmospheric air must be constantly carried through the fuel: the quantity and force of this current must depend on the quantity and quality of the fuel to be consumed. It must be such that it shall supply sufficient oxygen to the fuel to maintain the combustion, and not more than sufficient, since

* For the full explanation of this process, see Tract on Fire.

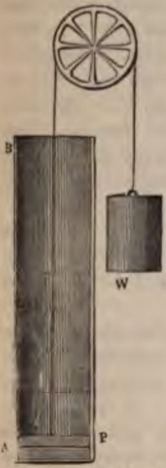
any excess would be attended with the effect of absorbing the heat of combustion, without contributing to the maintenance of that effect.*

The mechanical force of steam is developed in three ways—I. By evaporation; II. By expansion; and III. By condensation. We shall accordingly explain these severally.

7. I.—FORCE DEVELOPED BY EVAPORATION.

To render intelligible the manner in which a mechanical power is developed in the conversion of water into steam, and the circumstances which attend that remarkable physical change, we will suppose a quantity of pure water deposited in the bottom, A, of a tube, B A, fig. 1. To render the explanation more simple, we will suppose that the area of the section of the tube is equal to a square inch, and that the quantity of water deposited in it is a cubic inch. We will further imagine the tube to be glass, so that the phenomena developed in it may be visible. Let a piston, P, be imagined to be fitted in the tube, air tight and steam tight, and to be placed in immediate contact with the surface of the water, so as to exclude all communication between the water and the air above the piston. In this case the piston would be pressed upon the water by the pressure of the atmosphere upon a square inch of surface added to the weight of the piston itself. But the former pressure is equal to 15 lb.,† and therefore the pressure on the surface of the water will exceed the weight of the piston by 15lb. Now to simplify our explanation by excluding all reference to the atmospheric pressure, and the particular weight of the piston, P, we shall suppose both of these exactly counterpoised by the weight, W, so that the piston shall be placed in contact with the surface of the water, without, however, exerting any pressure upon it.

Fig 1.



These conditions being understood, let a weight, say of 15lb., be placed upon the piston P, and let a fire, a lamp or any other regular source of heat, be applied to the bottom of the tube. If a thermometer were immersed in the water under the piston, the following effects would then be observed:—

* See Tract on Fire.

† See Tract on Air.

The thermometer would rise, the piston maintaining its position, and this would continue until the thermometer would rise to the temperature of 212°. Upon rising to that temperature the thermometer would remain stationary, and at the same time the piston, P, would begin to rise, leaving a space apparently empty between it and the surface of the water. The lamp, or fire, still continuing to impart the same heat to the water, the thermometer nevertheless will remain stationary at 212°, but the piston will continue to rise higher and higher in the tube, and if the depth of the water in the bottom of the tube be measured, it will be found that it is constantly diminished. If a sufficiently exact measurement of the decrease of the depth of water, and the height to which the piston is raised could be made, it would be found that the one would bear a fixed and invariable proportion to the other, the height of the piston being always 1669 times the decrease of the depth of water.

In fine, if this process were continued for a sufficient time, and if the tube had sufficient length, the water would altogether disappear from the bottom of the tube, and the piston would be raised 1669 inches, or 139 feet very nearly. For the convenience of round numbers, in a case where the most extreme arithmetical accuracy is not needed, we shall then assume that the piston loaded with 15lb. has been raised 140 feet.

8. After this has taken place the tube below the piston will appear to be quite empty, the water having disappeared, and no visible matter having taken its place. If, however, the tube and its contents were weighed, they would be found to have the same weight precisely as they had when the water was deposited under the piston.

The phenomenon is easily explained. The heat applied to the tube has converted the visible liquid water into invisible steam. It is a great but very common error to suppose that the whitish cloudy vapour which is seen to issue from the safety valve of an engine, or the funnel of a locomotive, or the spout of a boiling kettle, is steam. The semi-transparent matter which floats in the air, and continues to be visible for some time after it escapes from the boiler, is in fact not steam, but water existing in very minute particles, produced by the condensation of the steam by the contact of the colder air. When those particles coalesce and form small drops of water, they either fall to the ground or are evaporated at a lower temperature, and in either case disappear. If the vapour issuing from the safety valve of an engine, or the spout of a boiling kettle, be closely examined, it will not be found to have that cloudy semi-transparent appearance until it has passed to some distance from the point from which it issues.

Pure steam is, in fact, a transparent and invisible elastic fluid like air, and this explains how it is, that in the tube, A B, the space below the piston, after the evaporation of the water, *appears* to be empty. It is, however, no more empty than if it were filled with air. It is filled with the invisible elastic vapour into which the water has been converted by the heat which has been applied to it.

9. It remains now to show what is the quantity of mechanical force evolved in this conversion of water into steam, and what quantity of heat has been absorbed in producing it.

From what has been stated above, it appears that the water in passing into vapour has swelled into 1669 times its original bulk, being subject to a compressing force of 15lb. upon the square inch. In thus expanding, the weight of 15lb. has been raised 140 feet, an effect which is mechanically equivalent to 140 times 15lb., that is 2100lb. raised one foot.

10. To estimate the quantity of heat absorbed in producing this effect, let us suppose that in the commencement of this process, the water under the piston has the temperature of 32°, and that the lamp, or other source of heat, which is applied to it acts with such uniformity as to impart exactly the same quantity of heat per minute.

Let the time which elapses between the first application of the lamp and the moment at which the water attains the temperature of 212° and begins to be evaporated, be observed, and also the interval between the commencement of evaporation and the total disappearance of the water. It will be found that the latter interval is $5\frac{1}{2}$ times the former. It follows consequently that to convert water at 212° into steam requires $5\frac{1}{2}$ times as much heat as is necessary to raise the same water from 32° to 212°, or what is the same, the quantity of heat which would convert water at 212° into steam would increase the temperature of the same water by $5\frac{1}{2}$ times 180°, that is by 990°, if it had remained in the liquid state.

It follows also, that to convert water at 32° into steam will take $6\frac{1}{2}$ times as much fuel as would be sufficient to boil the same water.

11. It may be asked, what becomes of the enormous quantity of heat thus imparted to the water during the process of its evaporation, seeing that the water itself receives no increase of temperature, being maintained steadily at 212°, and that the steam into which it is converted has the same temperature? This is answered by showing that the entire quantity of heat which thus disappears to the thermometer is absorbed by the steam, and must in fact be regarded as the immediate cause of its maintaining the elastic or vaporous form. That it is actually contained in the steam, though

its presence is not indicated by the thermometer, is incontestably established by the result of the following process :—

Let the steam, at 212°, which has been evolved from a cubic inch of water at 32°, be mixed with $5\frac{1}{2}$ cubic inches of water at the temperature of 32°. The steam will be at once reconverted into water, and the mixture will be $6\frac{1}{2}$ cubic inches of water, the temperature of which will be 212°. Thus it appears that the steam at 212°, when reconverted into a cubic inch of water at 212°, parts with as much heat as suffices to raise $5\frac{1}{2}$ cubic inches of water from 32° to 212°, which is exactly the quantity of heat which disappeared while the water was converted into steam.

The heat which is thus contained in steam, without affecting the thermometer, is said to be LATENT, and the latent heat of steam is therefore stated to be about 1000°, the meaning of which is, that to convert boiling water into steam as much heat must be imparted to it as would raise it 1000° higher in temperature if it did not undergo that change of state.

12. In the preceding explanation we have supposed the piston P to carry a weight of 15 lb. Let us now consider in what manner the phenomena would be modified if it were loaded with a greater or less weight.

If it were loaded with 30lb., the conversion of the water under it into steam would not commence until the temperature is raised to $251\frac{1}{2}$°, and when the whole of the water is evaporated, the piston would be raised to the height of only 883 inches, being a very little more than half the height to which it was raised when the evaporation took place under half the pressure. For all practical purposes, then, we shall be sufficiently accurate in stating, that when the weight on the piston P is doubled, it will be raised by the evaporation of a given quantity of water to half the height.

In general, in whatever proportion the weight on the piston is increased, the height to which it is raised by the evaporation of a given quantity of water will be decreased, and in whatever proportion the weight is diminished, the height will be increased.

13. It follows, therefore, that in all cases, whatever be the pressure under which the evaporation takes place, the same mechanical force is developed by the evaporation of the same quantity of water. Strictly speaking, there is a little more force with greater pressures, but the difference is so small, and so nearly balanced by certain practical disadvantages attending high pressures, that it may be wholly disregarded.

Since the amount of force developed by each cubic inch of water evaporated is equivalent to 2100 lb. raised one foot, we shall be sufficiently near the truth in stating in round numbers that such a force is equivalent to a ton weight raised a foot high.

It appears also, that under a pressure of 15 lb. per square inch, water swells into 1669 times its bulk when it is converted into steam. Since a cubic foot is 1728 cubic inches, and since the mean atmospheric pressure is a little under 15 lb., it may be stated with sufficient precision for all practical purposes, that a cubic inch of water, evaporated under the mean atmospheric pressure, will produce a cubic foot of steam.

14. II.—FORCE DEVELOPED BY EXPANSION.

Steam, in common with all vapours and gases, exerts a certain mechanical force by its property of expansibility.

To render this source of mechanical power intelligible, let us suppose the piston P loaded at first with 60 lb. for example, and under this pressure let the water be evaporated, and the piston raised to the height of 35 feet. The power thus developed will be that due to evaporation alone. But after the evaporation has ceased, and when the piston, with its load of 60 lb., is suspended at the height of 35 feet, let 15 lb. be taken from it, so as to leave a load of only 45 lb. The pressure below the piston being then greater than its load, it will be elevated, and as it is elevated, the steam below it increasing in volume, will be diminished in pressure in the same proportion, until the piston is raised to a height equal to one-third part of 140 feet, when the pressure below it will be equal to the load upon it, and it will remain suspended. During this expansive action of the steam, therefore, 45 lb. have been raised through a height equal to a difference between $\frac{1}{3}$ and $\frac{1}{4}$, that is, through $\frac{1}{12}$ of 140 feet.

At this point let 15 lb. more be supposed to be removed from the piston, so that its load shall be reduced to 30 lb. The pressure below it being, as before, greater than its load, the piston will be raised, and will continue to rise, until it rise to a height equal to half of 140 feet, when the pressure, reduced by expansion, will become equal to the load, and the piston will again become suspended.

In this interval 30 lb. have therefore been raised by the expansive action of the steam, through the difference between $\frac{1}{2}$ and $\frac{1}{3}$, that is, through $\frac{1}{6}$ of 140 feet.

Finally, suppose 15 lb. more to be removed, and the piston will rise with the remaining 15 lb. to the height of 140 feet, so that, in this last expansive action, 15 lb. are raised through a height equal to the half of 140 feet.

It is evident that the result of the expansive action may be indefinitely varied by varying the extent of its play.

Meanwhile, whatever may be its amount, it is clearly quite

independent of the process of evaporation, and, indeed, of every property by which vapours are distinguished from air or gases, inasmuch as these latter, being similarly compressed, would similarly expand, and would develope in their expansion precisely the same force.

15. III.—FORCE DEVELOPED BY CONDENSATION.

It has been already explained * that as heat converts water into steam, so, on the other hand, will cold convert steam into water; and as water, in passing from the liquid to the vaporous state, is swelled into a vastly increased volume, so, on the other hand, in passing from the vaporous to the liquid state, it suffers a proportionate diminution of volume. Thus if the evaporation take place under a pressure of 15 lb., a cubic inch of water is dilated into a cubic foot of steam. Now, if by the application of cold this steam is converted into water, it will resume its original dimensions, and will become a cubic inch of water. This change of vapour into water has therefore been called CONDENSATION, inasmuch as the matter of which it consists, contracting into a much smaller volume, is rendered proportionally more dense.

This property has supplied another means of rendering steam a mechanical agent. Let us suppose that after the piston P, fig. 1, has been raised 140 feet high by the evaporation of a cubic inch of water, the counterpoise, W, having descended through the same height, an additional weight of 15 lb. is placed upon W, and, at the same time, the lamp withdrawn from the tube and cold applied to its external surface. The steam by which the piston was raised will then be converted into water, or condensed, and will, as at first, fill the bottom of the tube to the height of an inch. The space within the tube above the surface of the water extending to the height of 140 feet, will then be a vacuum, and the atmospheric pressure acting above the piston, not being resisted by any corresponding pressure below it, will force the piston down with a force of 15 lb., and will raise the weight W, loaded with the additional 15 lb. through the same height.

Thus, it appears that when steam is condensed, or reconverted into water, by producing a vacuum, it developes a mechanical force equal to that which was developed in the conversion of water into vapour.

The mechanical power developed by the evaporation of water has been sometimes called the *direct* power, and that produced by the conversion of vapour into water the *indirect* power of

* See Tract on Water.

steam, because the immediate agent in the former case is the elastic force of the steam itself, while the agent in the latter case is the atmospheric pressure, to which effect is given by the vacuum produced by the condensation of steam.

16. The three sources of mechanical power which have been explained, have been used sometimes separately and sometimes together in different forms of steam engine.

In the class of engines commonly called high-pressure engines, the direct power alone is used. In a class of engines, now out of use, called atmospheric engines, the indirect power alone was used. In the engines most generally used in the arts and manufactures, known as low pressure or condensing engines, both powers are used.

To obtain the mechanical effect of the vacuum produced by the condensation of steam, it is not necessary that the atmospheric pressure should be used. If we suppose that while the vacuum is produced below the piston P, steam having a pressure equal to that of the atmosphere be admitted to the upper side of it, the piston will be urged downwards into the vacuum with the same force exactly as if the atmosphere acted upon it.

And, in effect, this is the method by which the indirect force of steam is rendered effective in all engines as at present constructed, the piston being in no case exposed to the atmosphere.

17. In the preceding illustration of the power of steam, we have supposed the piston P to have the area of a square inch, and to be raised continuously to the height of 140 feet. But it is evident that such conditions are neither necessary nor practicable. If the piston had an area of ten square inches the same amount of evaporation would raise it to the tenth part of the height; but the force with which it would be raised, being at the same time increased in a tenfold proportion, the mechanical effect would be the same, for it is evident that whether 15 lb. be raised 140 feet, or 10 times 15 lb. be raised the 10th part of 140 feet, the same mechanical effect would be produced.

The piston acted upon by the steam, instead of being continuously driven in one direction, may be alternately elevated and depressed, and still the same amount of power will be developed. Thus the evaporation may be continued until the piston has been raised 10 feet. The steam which raised it may then be condensed, and the piston having descended to the bottom of the tube, it may again be raised 10 feet by evaporation as before, and this may be continued indefinitely. In this way, by means of a *short* tube or cylinder, the mechanical effect attending the *evaporation* of any quantity of water may be obtained, and this, in

fact, is what is accomplished in steam engines as they are practically worked.

The direct and indirect powers of steam may also be easily combined as well in the ascent as in the descent of the piston. If we suppose the upper part of the tube, instead of being open to the atmosphere, to communicate with a reservoir of water, to which, like the bottom of the tube, a lamp or other source of heat is applied, steam may be admitted above the piston P as well as below it. Now, if such be the case, it is easy to imagine how the piston can be at the same time affected by the direct and indirect power of the steam. Thus, if we suppose that a vacuum has been formed above it, by the condensation of steam, admitted from the upper reservoir, while steam produced from the lower reservoir acts below it, the piston will be forced upwards by the combined effect of the direct action of the steam below and the indirect action of the condensed steam above, and when the piston has been thus raised, we can imagine that while steam is admitted above it from the upper reservoir, that which is below it may be condensed, in which case it will be forced down by the combined effect of the direct action of the steam above it and the indirect action of the condensed steam below it, and it is evident that such alternate action may be indefinitely continued.

Such is the effect of the broad principle upon which all engines of the class called condensing, or low-pressure engines, are constructed. In their details there are numerous points of great practical importance and of much interest in a mechanical point of view. These arrangements, however, not affecting the principle of steam, regarded in its most general sense, need not here be further noticed. On a future occasion we shall explain such of them as have the greatest popular interest.

18. The apparatus by which the combustion of the fuel is effected, and by which the heat evolved is transmitted to the water to be evaporated, are furnaces and boilers of very various forms and construction, according to the circumstances in which they are applied, the one being adapted to the other, so that as much of the heat shall arrive at the water as the circumstances of their application permit.

19. The quantity of water which would be evaporated, if all the heat evolved in the combustion of a given weight of fuel could be transmitted to the water, is the THEORETICAL EVAPORATING POWER of the fuel, and the quantity of water actually evaporated by it is the PRACTICAL EVAPORATING POWER.

The theoretical evaporating power varies with the quality of the fuel. A given weight of certain species of coal will evolve in combustion a greater or less quantity of heat than other species.

In general, it may be stated that the strongest coals, meaning by that term those which have the greatest evaporating power, are those which are richest in carbon.

The practical evaporating power of a given species of coal varies with the form, construction, and magnitude of the furnace and boiler. That portion of the heat which does not reach the water is dissipated in various ways. A part of it is lost by radiation from the grate; a part by radiation from the boiler; a part is carried by the heated gases of combustion into the chimney. The first two sources of waste of heat are reduced to a very small amount by a variety of ingenious contrivances. But the last is indispensable to the maintenance of the combustion, and ought to be considered as the power by which the furnace is worked, rather than a waste of heat.

20. The grate upon which the fuel is placed is surrounded on every side by parts of the boiler within which water is contained.

In some boilers, even the ash-pit is a part of the surface of the boiler under which there is water. In this case, all the heat radiated from the grate, and the fuel upon it, is transmitted to the boiler; and in all cases the furnace is surrounded on every side, except the bottom of the grate or ash-pit, with surfaces having water within them.

21. The waste of heat by radiation from the surfaces of the boiler, steam-pipes, cylinder, and other parts of the machinery in which steam is contained, or through which it passes, is diminished by various expedients, which in general consist in surrounding such surfaces with packing, casing, or coating, composed of materials which are non-conductors, or at least very imperfect conductors of heat.

In some cases the boiler is built round in brick work. In Cornwall, where economy is carried perhaps to a greater extent than elsewhere, the boiler and steam-pipes are surrounded with a packing of sawdust, which being almost a non-conductor of heat, is impervious to the heat proceeding from the surfaces with which it is in contact, and consequently confines all the heat within the boiler. In marine boilers it has been the practice recently to clothe the boiler and steam-pipes with a coating of felt, which is attended with a similar effect. When these remedies are properly applied, the loss of heat proceeding from the radiation of the boiler is reduced to an extremely small amount. The engine houses of some of the Cornish engines, where the boiler generates steam at a very high temperature, are frequently maintained at a lower temperature than the external air, and on entering them they have in a great degree the effect of a cave.

The cylinders are often cased in wood. The boilers of locomotive engines are always covered with a coating of boards.

By these and many other expedients for the economy of heat, and more especially by the extensive application of the expansive force of steam, the mechanical power evolved from the combustion of coals has been increased to an almost incredible extent.

22. A system of public inspection, of the performance of the engines worked in the mining districts of Cornwall, was established about forty years ago, which has been continued to the present time with the greatest advantage to the mining interests in particular, and to the engineering and commercial world in general. An exact account is kept, and periodical reports published of the quantity of fuel consumed by each engine, and the quantity of work done, the latter being expressed always by an equivalent weight, raised one foot high. The ratio of the fuel consumed to the weight thus raised is called the DUTY of the engine.

23. The improved efficiency of steam machinery is illustrated in a striking manner by these reports. It appears by them, that, in 1813, the average mechanical effect of a bushel of coals, applied in the best of the Cornish engines, was 11785 tons raised one foot. In 1837, this duty was 38935 tons raised one foot. The duty was therefore augmented in the ratio of 1 to $3\frac{1}{3}$.

The increase of the mechanical efficiency of fuel has still gone on from year to year, and it may now be considered that a bushel of coals, of average quality, applied under good conditions of economy to the most efficient engines, is capable of producing a mechanical effect equivalent to 50000 tons raised one foot.

24. It follows, therefore, that a pound of coal has a mechanical virtue expressed by six hundred tons weight raised one foot high.

25. It is only by comparison with other physical agents that we can duly appreciate this prodigious mechanical power of coals.

It is calculated that the materials composing the great pyramid of Egypt might have been elevated from the level of its base to their actual places by the combustion of 700 tons of coal.

26. Those of the Menai Bridge might have been raised from the level of the water by 400 lb. of coal.

27. A train of coaches weighing 80 tons, and conveying 240 passengers, is drawn from Liverpool to Birmingham, and back from Birmingham to Liverpool by the combustion of 4 tons of coke, the cost of which is *5l.* To carry the same number of passengers daily on a common road would require an establishment of 20 stage coaches and 3800 horses.

The circumference of the earth measures twenty-five thousand miles; if it were begirt with an iron railway, such a train as above-described, carrying two hundred and forty passengers, would be drawn round it by the combustion of about three hundred tons of coke, and the circuit would be accomplished in five weeks.

28. The enormous consumption of coals produced by the application of the steam-engine in the arts and manufactures, as well as to railways and navigation, has of late years excited the fears of many as to the possibility of the exhaustion of our coal-mines. Such apprehensions are, however, altogether groundless. If the present consumption of coal be estimated at sixteen millions of tons annually, it is demonstrable that the coal-fields of this country would not be exhausted for many centuries.

But in speculations like these, the probable, if not certain progress of improvement and discovery ought not to be overlooked; and we may safely pronounce that, long before such a period of time shall have rolled away, other and more powerful mechanical agents will supersede the use of coal. Philosophy already directs her finger at sources of inexhaustible power in the phenomena of electricity and magnetism. The alternate decomposition and recomposition of water, by electric action, has too close an analogy to the alternate processes of vaporisation and condensation, not to occur at once to every mind: the development of the gases from solid matter by the operation of the chemical affinities, and their subsequent condensation into the liquid form, has already been essayed as a source of power. In a word, the general state of physical science at the present moment, the vigour, activity, and sagacity with which researches in it are prosecuted in every civilised country, the increasing consideration in which scientific men are held, and the personal honours and rewards which begin to be conferred upon them, all justify the expectation that we are on the eve of mechanical discoveries still greater than any which have yet appeared; that the steam-engine itself, with its gigantic powers, will dwindle into insignificance in comparison with the energies of nature which are still to be revealed; and that the day will come when that machine, which is now extending the blessings of civilisation to the most remote skirts of the globe, will cease to have existence except in the page of history.

INDEX TO VOLUMES III. AND IV.